REPORT #
RRTAC 83-4

Workshop Proceedings: Effects of Coal Mining on the Hydrology of Alberta's Eastern Slopes

Heritage Fund

Alberta

LAND CONSERVATION AND
RECLAMATION COUNCIL
Reclamation Research
Technical Advisory Committee

REPORT #

RRTAC 83-4

WORKSHOP PROCEEDINGS:

EFFECTS OF COAL MINING ON THE HYDROLOGY OF ALBERTA'S EASTERN SLOPES

13 December 1983

EDMONTON, Alberta

Edited by

P.F. Ziemkiewicz

This Workshop was organized by the

Reclamation Research Technical Advisory Committee

of the

Alberta Land Conservation and

Reclamation Council

ALBERTA'S RECLAMATION RESEARCH PROGRAM

The regulation of surface disturbances in Alberta is the responsibility of the Land Conservation and Reclamation Council. The Council executive consists of a chairman from the Department of the Environment and two deputy chairmen from the Department of Energy and Natural Resources. Among other functions, the Council oversees programs for reclamation of abandoned disturbances and reclamation research. The reclamation research program was established to provide answers to the many practical questions which arise in reclamation. Funds for implementing both the operational and research programs are drawn from Alberta's Heritage Savings Trust Fund.

To assist in technical matters related to the development and administration of the research program the Council appointed the Reclamation Research Technical Advisory Committee (RRTAC). The Committee first met in March, 1978 and consists of eight members representing the Alberta Departments of Agriculture, Energy and Natural Resources, Environment and the Alberta Research Council. The Committee meets regularly to update research priorities, review solicited and unsolicited research proposals, arrange workshops and otherwise act as a referral and coordinating body for Reclamation Research.

Additional information on the Reclamation Research Program may be obtained by contacting:

Dr. P.F. Ziemkiewicz, Chairman
Reclamation Research Technical Advisory Committee
Alberta Energy & Natural Resources
9915-108 Street
EDMONTON, Alberta (427-8042)

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RECLAMATION RESEARCH REPORTS

Available From: Publication Services
Queen's Printer
11510 Kingsway Avenue
T5G 2Y5 *

1. TITLE: The Alberta Government's Reclamation Research Program 1981, #RRTAC 82-3

   AUTHOR(S): P.F. Ziemkiewicz

   DESCRIPTION: This Report details the Reclamation Research Program indicating priorities, project status, researchers, results and expenditures.

2. TITLE: Manual of Plant Species Suitability for Reclamation in Alberta, 2 Vols. #RRTAC 80-5

   AUTHOR(S): L.E. Watson, R.W. Parker, P.F. Polster

   DESCRIPTION: Forty-three grass, fourteen forb and thirty-four shrub and tree species are assessed in terms of their fitness for use in Reclamation. Information presented includes: Range Maps, Growth Habit, Propagation, Tolerances and Availability.

3. TITLE: Proceedings: Workshop on Coal Ash and Reclamation. #RRTAC 81-3

   AUTHOR(S): P.F. Ziemkiewicz, R. Stein, R. Leitch, G. Lutwick

   DESCRIPTION: Presents nine Technical Papers on The Chemical, Physical and Engineering Properties of Alberta Fly and Bottom Ashes, Revegetation of Ash Disposal Sites and Use of Ash as a Soil Amendment. Workshop discussions and summaries are also included.

4. TITLE: 1980 Survey of Reclamation Activities in Alberta. #RRTAC 81-2

   AUTHOR(S): D.G. Walker, R.L. Rothwell

   DESCRIPTION: This survey is an update of the original Report conducted in 1976 on Reclamation Activities in Alberta, includes Research and Operational Reclamation, locations, personnel etc.

5. TITLE: A Bibliography of Baseline Studies in Alberta: Soils, Geology, Hydrology and Groundwater. #RRTAC 82-2

   AUTHOR(S): C.G. Powter, H.P. Sims

   DESCRIPTION: This Bibliography provides baseline information for persons involved in Reclamation Research or in the Preparation of Environmental Impact Assessments. Materials, up to date as of Dec. 1981 are available from the Alberta Environmental Library.

6. TITLE: Proceedings: Workshop on Reconstruction of Forest Soils in Reclamation. #RRTAC 80-4

   AUTHOR(S): P.F. Ziemkiewicz, S.K. Takyi, H.F. Regier

   DESCRIPTION: Experts in the Field of Forestry and Forest Soils Report on Research relevant to Forest Soil Reconstruction and discuss the most effective means of restoring forestry capability of mined lands.

7. TITLE: Land Surface Reclamation: An International Bibliography 2 Vols. #RRTAC 82-1

   AUTHOR(S): H.P. Sims, C.B. Powter

   DESCRIPTION: Literature pertinent to Reclamation in Alberta is listed in Vol. I and is also on the University of Alberta Computing System. The keyword Index and Computer Access Manual comprises Vol. II

8. TITLE: The Role of Organic Compounds in Salinization of Plains Coal Mining Sites #RRTAC 80-3

   AUTHOR(S): N.S.C. Cameron et al.

   DESCRIPTION: This is a literature review of the chemistry of sodic mine spoil and the changes expected to occur in groundwater.

* A $5.00 fee is charged for each publication to cover handling and postage. Please make cheque payable to: "Provincial Treasurer of Alberta.

EFFECTS OF MINING ON HYDROLOGY OF THE EASTERN SLOPES
A WORKSHOP
ORGANIZED BY THE RECLAMATION RESEARCH TECHNICAL ADVISORY COMMITTEE

DATE: 13 December, 1982

PLACE: EDMONTON, Alberta

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* NO MANUSCRIPT SUBMITTED - DISCUSSION ONLY

SUMMARY

The impacts of Coal Mining on the Hydrology of the Eastern Slopes have long excited interest in Alberta. The Hudson's Bay watersheds along the Eastern Slopes of the Rocky Mountains are the major source of water for domestic and industrial users across Alberta and Saskatchewan.

Although most Eastern Slopes mining activity occurs in the Arctic drainages, watershed protection remains a major concern for recreational fisheries users as well as local domestic and industrial users.

In December 1982 the Reclamation Research Technical Advisory Committee organized a workshop on the interaction between Coal Mining and Hydrology in the Eastern Slopes. The workshop objectives included:

1. Definition of existing data bases and data gathering systems.
2. Interpretation of these data in the mining context.
3. Identification of further research needs.

Participants included Government and Industry staff as well as Researchers. Bringing this sort of talent together presented a unique opportunity. To ensure that even the most reticent individuals had the opportunity to express their views a questionnaire was distributed to all of the participants. The intent was to poll their perceptions of research priorities in light of information presented during the workshop and their own experiences. Nearly one third (32.6%) of the group responded and their views are summarized in the last Chapter "Research Priorities, Questionnaire Summaries." Several excellent points were brought out. For example, the most pressing need is still to predict water handling requirements and to design appropriate water management systems. The unknown factors in the equation include:

1. Changes in soil permeability and runoff pathway from clearance through mining and various stages of revegetation.

2. Which post-mining landscape configurations and revegetation patterns and strategies will yield the desired results most efficiently and

3. The maximum amounts of water which a system must handle (including snowmelt and rain) and how frequently runoff events of a given intensity are likely to recur.

Other items which were mentioned include cumulative effects of mining on River Basins, the regulatory system, the effects of different sediment types on fisheries and groundwater contribution to stream flows.

In conclusion and on behalf of all the participants I would acknowledge the excellent job done by the Speakers, particularly those who found time to commit their work to writing for these proceedings.

Paul F. Ziemkiewicz

EFFECTS OF MINING ON HYDROLOGY OF THE EASTERN SLOPES

HYDROLOGY OF THE PRE-MINING LANDSCAPE

by: A. DeBoer, P. Eng.
Alberta Environment
Technical Services Division

ABSTRACT

An overview of recorded runoff in the east slopes foothills zone of Alberta shows that there is a sufficient water supply in this region to meet anticipated water demands for coal mining developments. However, offstream storage during low flow periods may be required to meet the water demand and the amount of storage required will be dependent on the location of the diversion and the instream flow requirements at the diversion point. The eastern slopes occupy a zone of rapidly changing climatic and physiographic conditions and the transposing of data from a gauged watershed to an ungauged watershed must carefully evaluate the factors which influence runoff to ensure that the two watersheds share similar hydrometeorological conditions.

1. INTRODUCTION

1.1 Factors Influencing Runoff

Surface water runoff is, by nature, variable because the factors which influence runoff (precipitation, evaporation, transpiration, interception, infiltration and storage) are all variable in both time and spatial distribution over the drainage basin during a runoff event. Climatic factors include mainly the effects of various forms and types of precipitation, interception, evaporation, and transpiration. Physiographic factors include both basin characteristics and channel characteristics. Basin influences include, size, shape, and slope of drainage area, permeability and capacity of groundwater formations, presence of lakes and swamps, and land use. Channel characteristics are related mostly to hydraulic properties of the channel which govern the movement of streamflow and channel storage capacity. Recorded streamflow is the end product of these many factors and provides the most suitable means for quantitative hydrologic investigations.

The factors affecting runoff generally tend to cause large drainage areas to behave differently from small drainage areas on the basis of hydrologic behaviour. Large drainage basins generally show prominent channel storage influences while small drainage basins are generally sensitive both to high-intensity rainfalls of short duration and to land use. Recorded streamflow data exhibits a high degree of variability and is a function of the sensitivity of the drainage basin to the factors which influence runoff.

1.2 Scope of the Study

This presentation outlines the types of hydrometeorological data available and where this data may be obtained. A general overview of surface water runoff for the pre-mining landscape in the east slopes foothills zone provides insight into the factors influencing runoff pertinent to transposing data from a gauged watershed to an ungauged watershed. A case study for a water supply assessment and estimation of flood frequencies for the headwaters of the McLeod River gives an interpretation of this data in the context of some design parameters pertinent to the mining industry.

2. DATA GATHERING SYSTEMS

2.1 Meteorological Observations

2.1.1 Data Publication

Each year the Atmospheric Environment Service (AES) publishes climate data and information in a number of current or historic periodicals. Most of the publications are available on subscription. Many one-time publications containing specialized information are issued on occasion. Information about the contents and format of these publications and how copies may be obtained is available from AES on request.

Generally, the front-line supplier of climate information is the regional climatological specialist. For items of an inter-regional, national or international nature, enquiries should be directed to the Canadian Climate Center. The name and address of the office from which subscriptions or copies of publications may be obtained are provided below.

REGIONAL OFFICE
Director, Western Region
Atmospheric Environment Service
Argyll Center
6325 - 103 Street
Edmonton, Alberta T6H 5H6
Attn: Scientific Services

CANADIAN CLIMATE CENTER
Assistant Deputy Minister
Atmospheric Environment Service
4905 Dufferin Street
Downsview, Ontario M3H 5T4
Attn: Climatological Services Division

2.1.2 Temperature Summary

Air temperature measurements are made from thermometers set in a standard, double louvered, wooden screen. The screen is mounted on a stand such that the maximum and minimum thermometers are approximately 1.5 meters above ground. Daily temperatures are shown in Celsius degrees and tenths. The mean temperature for the day is the average of the daily maximum and daily minimum temperatures.

2.1.3 Precipitation Summary

The standard Canadian rain gauge is used to collect and measure the amount of rain, drizzle, freezing rain, freezing drizzle, or hail to the nearest 0.1 of a millimeter. Snowfall is measured with a standard snow ruler by averaging the depth of freshly fallen snow at representative points. At ordinary climatological stations, the water equiva-

lent of the snow is obtained by dividing the amount of snow by 10. At principal stations, the water equivalent is determined by melting the snowfall. Total daily precipitation is recorded as rainfall plus the water equivalent of the snowfall, while daily snowfall is recorded as the water equivalent of freshly fallen snow.

2.1.4 Monthly Summary

A monthly summary of "the number of days with" for a selection of 11 meteorological elements observed at stations taking hourly observations is also presented in the AES Monthly Record of Meteorological Observations. These elements include temperature ≤ 0.0°C, thunderstorm day, rain or drizzle, freezing precipitation, hail, snow, measurable precipitation, fog, smoke or haze, blowing dust or blowing sand and blowing snow.

2.1.5 Synoptic Observations

Main synoptic observations are taken at 6 hour intervals and include station pressure, sea level pressure, vapour pressure, air pressure, air temperature, and dew point temperature. Visibility statistics show the number of days in the month when visibility was less than 1 km, between 1 and 10 km, and greater than 10 km for the specified hour. For cloud amount, the proportion of the sky covered by cloud is expressed in tenths; zero tenths indicate a cloudless sky and ten tenths a completely overcast sky.

2.1.6 Wind

At regular hourly-observing stations, the speed reported is an average of the readings observed over a one minute interval close to the hour and directions are to the nearest 10 degrees. At climatological stations, wind speed is summarized over the hour and direction reported as that prevailing during the hour, recorded to 8 points of the compass. Wind direction is the direction from which the wind is blowing and is given as the true bearing rather than magnetic. The maximum observed hourly wind and the maximum observed gusts, if observed, are also provided.

2.1.7 Bright Sunshine

Bright sunshine in hours and tenths are presented at observation sites by day and for the month. Recorded sunshine less than 0.05 hours is indicated by 00. The percent of possible duration refers to the duration of sunshine that is observed compared to the duration of sunshine that would be observed at the station if the terrain was level and no obstructions existed, and the sky was clear throughout the day.

2.1.8 Recording Rain Gauge Data

The AES Tipping Bucket Rain Gauge is the standard instrument for measuring rate of rainfall. The data contains the maximum precipitation amounts, expressed in tenths of a millimeter of water, that have been recorded in each month for selected durations from 5 minutes to 24 hours.

Data from some other types of recording gauges and storage gauges are published semi-annually in SUPPLEMENTARY PRECIPITATION DATA. More complete rainfall intensity data may be obtained from AES, where the original data and summaries are on file.

2.1.9 Evaporation

Class "A" Pan evaporation estimates are also provided for a 24 hour period which begins after the morning observation and ending at the time of the morning observation of the following day. The total net water loss is the sum of water added by the observer to bring the water level in the pan to the tip of the fixed point gauge. On days with precipitation, the total net water loss is the difference between the amount of water collected from the nearby standard rain gauge and the mount of water removed from the pan to return the water level to the tip of the fixed point gauge. The accumulated wind run in kilometers above the surface of the pan and the monthly mean water and air temperatures are also provided. Total calculated lake evaporation for the month, expected from a hypothetical small lake at the same location as the pan, is calculated from the pan water losses using methods outlined in WMO Technical Note No. 83, Measurement and Estimation of Evaporation and Evapotranspiration.

2.2 Surface Water Data

2.2.1 Data Publications

Streamflow data in Alberta, on a network basis, are collected and published by the Inland Waters Directorate of the Federal Department of Fisheries and the Environment. Details on publications of data, summaries and reference indexes (as well as recent data which have not yet been published) may be obtained from the offices provided below.

REGIONAL OFFICE
Regional Chief
Water Resources Branch
Department of the Environment
Bag 2909
Postal Station 'M'
(Room 854,
220 - 4th Avenue S.E.)
CALGARY, ALBERTA
T2P 2M7

FEDERAL OFFICE
Director
Water Resources Branch
Department of the Environment
Ottawa, Ontario
K1A 0E7

2.2.2 Tabulation of Data

For gauging stations where a systematic record of water level or discharge was obtained during the year under review, a table of daily water level in meters or daily discharge in cubic meters per second is given where available. A summary of monthly and annual data is also provided below the table of daily data along with descriptive information about the gauging station.

A historical streamflow summary is available for gauging stations where systematic streamflow data have been obtained. This summary includes (1) a summary of monthly and annual mean discharges,

(2) annual maximum instantaneous discharges, (3) annual maximum and minimum daily discharges, (4) identification of the extreme recorded for the period of record, and (5) the annual total discharge in cubic decameters.

3. RUNOFF - A GENERAL OVERVIEW

3.1 Mean Annual Precipitation

In Alberta, precipitation is measured at several hundred locations throughout the province and Figure 3-1 shows the distribution of the annual precipitation. The greatest amount of precipitation occurs in the Rocky Mountains along the Alberta- British Columbia border and the least amount occurs in the south-east corner of Alberta. Precipitation in the east slopes foothills zone varies significantly between Rockies and the prairies and influences the runoff characteristics in the region.

When transposing runoff data from a gauged watershed to an ungauged watershed, the factors which influence runoff should be similar for the two watersheds. Precipitation is a significant climatic influence and the isolines shown on Figure 3-1 indicate regions of similar precipitation. Figure 3-1 may be used as a guide in selecting comparative watersheds sharing similar annual precipitation characteristics.

3.2 Mean Annual Runoff

Figure 3-2 shows the distribution of the annual runoff in the Province of Alberta and the isolines of runoff depth follow a pattern similar to the isolines of annual precipitation. When transposing runoff data from a gauged watershed to an ungauged watershed, the two watersheds should experience similar annual runoff characteristics. The annual runoff depth in millimeters is readily determined from historical streamflow summary data and is equal to the annual runoff volume in cubic decameters divided by the watershed drainage area in square kilometers.

3.3 Flood Frequency Estimates

Flood magnitudes are of interest to the mining community for the design of various open pit mining structures. Flood magnitudes exhibit a high degree of variability in the recorded runoff data and this parameter is often the most difficult parameter to accurately define in flood hydrograph analyses. This is due to both the physiographic characteristics of the region and the variability of precipitation in time, space, and frequency over the region.

In general, maximum specific runoff yields (peak flow per unit area) are greatest in the east slopes foothills zone of Alberta. This is attributed to high precipitation along the front range of the Rockies from cold low pressure systems entering Alberta. An anticlockwise flow of warm moist air is induced around the center of the low and this westward flowing air is forced to rapidly rise due to the proximity of the mountains, providing the large scale cooling required for signi-

VALUES ON THE MAP ARE IN MILLIMETRES AND ARE BASED ON THE 30-YEAR PERIOD 1941-1970

MILLIMETRES 200 400 800 1600 2400 MILLIMÈTRES

INCHES 7.9 15.7 31.5 63.0 94.5 POUCES

LES VALEURS DE LA CARTE SONT EXPRIMÉES EN MILLIMÈTRES ET FONDÉES SUR UNE PÉRIODE DE TRENTE ANS, DE 1941 À 1970

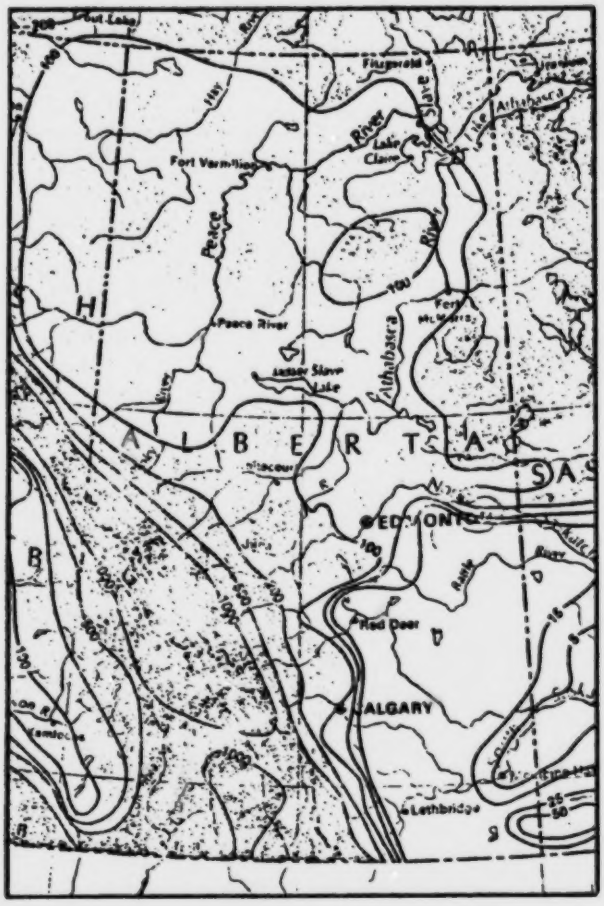
SOURCE: HYDROLOGICAL ATLAS OF CANADA

Alberta ENVIRONMENT	TECHNICAL SERVICES DIVISION HYDROLOGY BRANCH	ANNUAL PRECIPITATION
SUBMITTED A. DE BOER, P. ENG. DATE JAN. 1983	DESIGNED / CHECKED	
APPROVED M. MUSTAPHA, P. ENG. DATE JAN. 1983	DRAWN / CHECKED	SCALE 1: 10,000,000 DATE JAN. 1983 — FIGURE No. 3-1

MICROFILM DATE

DRAWING No.

FILE No.



VALUES ON THE MAP ARE IN MILLIMETRES

MILLIMETRES / MILLIMÈTRES

25 100 200 500 1000 2000

INCHES / POUCES

1 4 8 20 39 79

LES VALEURS DE LA CARTE SONT EN MILLIMÈTRES

NOTE: THE RUNOFF ISOLINES WERE ORIGINALLY COMPILED IN INCHES AND HAVE BEEN ADAPTED TO MILLIMETRES FOR THIS MAP.

ON AVAIT À L'ORIGINE DRESSÉ LES ISOLIGNES DE L'ÉCOULEMENT EN POUCES. MAIS ON LES A CONVERTIES EN MILLIMÈTRES POUR LA PRÉSENTE CARTE.

SOURCE : HYDROLOGICAL ATLAS OF CANADA

Alberta ENVIRONMENT	TECHNICAL SERVICES DIVISION HYDROLOGY BRANCH	ANNUAL RUNOFF
SUBMITTED A. DE BOER, P. ENG. DATE JAN. 1983	DESIGNED / CHECKED	
APPROVED M. MUSTAPHA, P. ENG. DATE JAN. 1983	DRAWN / CHECKED	SCALE 1 : 10,000,000 DATE JAN. 1983 — FIGURE No. 3-2

MICROFILM DATE

DRAWING No.

FILE No.

ficant amounts of precipitation to fall. Specific peak runoff yields in both the interior mountain range and the prairie region of Alberta are generally lower than in the east slopes foothills zone.

Examples of flood frequency estimates are given in Table 3-3 and illustrate both the diversity and variability exhibited by recorded runoff data. These examples show that the choice of selecting a gauged basin(s) to transfer data to an ungauged basin is important in determining reliable flood estimates. The flood data in the interior mountain zone, as represented by Bow River at Banff, shows a low specific yield for the 1:100 year flood and low variability in the ratio (1.7) of the 1:100 year flood to the 1:2 year flood. Flood estimates in the foothills zone, as represented by Elbow River above Glenmore Dam and Eunice Creek near Hinton, show high specific yields for the 1:100 year flood. However, the variability in the flood estimates are significantly different for these two stations and this difference may largely be attributed to the difference in size between the two drainage basins. The data for Prairie Creek near Rocky Mountain House, a foothills stream in close proximity to the prairie region of central Alberta, shows a low specific yield for the 1:100 year flood. Recorded data in the eastern slopes exhibits a wide range of runoff characteristics and the factors which influence runoff must be carefully evaluated when transposing data from a gauged watershed to determine runoff characteristics for an ungauged watershed.

TABLE 3-3

FLOOD FREQUENCY ESTIMATES

Station Number	05BB001	05BJ005	07AF005	05DB002
Station Name	Bow River at Banff	Elbow River above Glenmore Dam	Eunice Creek near Hinton	Prairie Creek near Rocky Mtn. House
Return Period (Years)	Annual Maximum Instantaneous Discharge ($m^3/sec/km^2$)			
100	0.174	0.688	0.748	0.240
20	0.150	0.363	0.485	0.151
5	0.124	0.140	0.264	0.078
2	0.101	0.047	0.124	0.034
Q_{100}/Q_2	1.7	14.6	6.0	7.1
area (km^2)	2210	1210	17.1	860
years of record	72	102	13	55

4 DATA INTERPRETATION - McLEOD RIVER HEADWATERS CASE STUDY

4.1 Water Supply Assessment

4.1.1 Information Required for Assessment

A Geographical Information

1. Name of the river or stream
2. Location of the proposed diversion
3. Area of the watershed upstream of the proposed diversion
4. Site plan showing:
   a) location of the point of diversion within the quarter section
   b) location of use of the diverted water
   c) location of any return flow

B Existing Character of the Streamflow

1. Determine the mean annual streamflow at the point of diversion.
2. Describe the variability of the annual streamflow by statistical analysis.
3. Determine the mean monthly streamflow for those months in which diversion are to be made.
4. Describe the variability of the monthly streamflow by statistical analysis.
5. If daily streamflow is relevant to the diversion, describe it in appropriate detail.

C Description of the Proposed Diversion

1. Purpose of the diversion
2. Quantity to be diverted annually
3. Quantity to be diverted each month
4. Anticipated daily rate of diversion
5. Similarly describe the quantity and timing of any return flows.

D Describe the Effect of the Proposed Diversion on the Stream

1. Indicate the proposed diversion as a percentage of the mean annual flow and the monthly mean flows.
2. Relate the proposed diversion to occurrences of low flows in order to evaluate the availability of water and to illustrate the impact of the diversion in a drought situation.
3. Determine if a requirement exists to ensure the passage of a given minimum flow downstream from the proposed diversion.

4.1.2 Preliminary Results

A preliminary water supply assessment of the McLeod River headwaters was completed to determine if sufficient water is available to meet currently anticipated water demands for coal developments in the area. Annual runoff yields were examined to assess the quantity of water available and annual minimum flows were examined to assess whether a shortage of water might occur during periods of low flow.

The available water supply for the Wolf Creek drainage basin was represented by station 07AG003 - Wolf Creek at Highway 16, which drains an area of 829 square kilometers, and the headwaters of McLeod River was represented by station 07AF002 - McLeod River above Embarras River, draining an area of 2560 square kilometers. Streamflow was recorded at these two stations from 1955 to 1980. The water supply for the Embarras - McLeod area (depicted in Figure 4-1) was determined by subtracting recorded flows on McLeod River above Embarras River and Wolf Creek at Highway 16 from recorded flows at station 07AG001 - McLeod River near Wolf Creek. McLeod River near Wolf Creek drains an area of 6320 square kilometers and has discharge records for the years 1915 to 1922, 1958 to 1968, and 1971 to 1980. This station has the longest available period of record and was used as a base station for adjusting annual runoff yields in the McLeod River system by a ratio of the estimates for the longer period of record divided by the estimates for the shorter period of record.

Table 4-1 gives the annual water supply estimates, based on a Pearson Type III frequency distribution, at the locations in the study area. For comparison purposes, the runoff yields are given in a runoff depth for the area contributing to the runoff volume. On an annual basis, there is an ample water supply for anticipated diversion quantities provided that there is a sufficient area contributing to drainage upstream of the proposed diversion.

TABLE 4-1

ANNUAL WATER SUPPLY ESTIMATES - McLEOD RIVER HEADWATERS

Exceedance Probability (%)	07AF002 McLeod River above Embarras River	07AG003 Wolf Creek at Highway 16	Embarras-McLeod area
	RUNOFF DEPTH (mm)		
.01	466	360	370
.10	348	241	263
.50	231	132	161
.90	147	65	91
.99	98	33	53

A Pearson Type III frequency analysis was also performed on recorded annual minimum daily discharges at the hydrometric stations and the results are summarized in Table 4-2. Depending on daily diversion quantities, Table 4-2 indicates that offstream storage in the McLeod River system would likely be required in the low flow periods of drought years because the minimum natural flows would likely be required for instream flow needs. The actual storage required for each project is a function of the magnitude of the withdrawal and the location of the source and is beyond the scope of this report. However, in general, storage requirements would likely be in the order of a two to four month water supply in the McLeod River drainage basin.

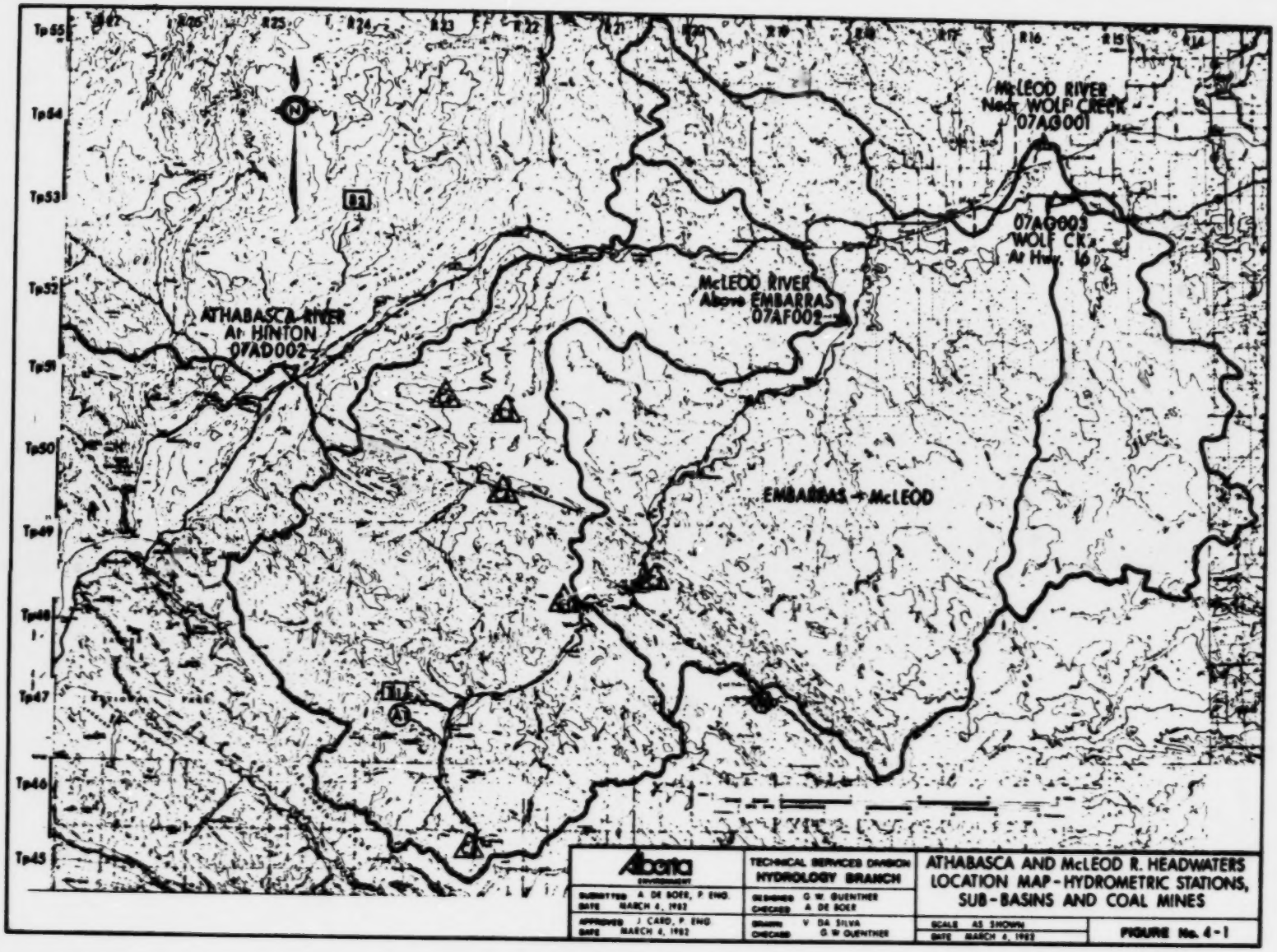

McLEOD RIVER
Near WOLF CREEK
07AG001
07AG003
WOLF CK's
At Hwy. 16
McLEOD RIVER
Above EMBARRAS
07AF002
ATHABASCA RIVER
At HINTON
07AD002
EMBARRAS + McLEOD
Tp55
Tp54
Tp53
Tp52
Tp51
Tp50
Tp49
Tp48
Tp47
Tp46
Tp45
R27
R26
R25
R24
R23
R22
R21
R20
R19
R18
R17
R16
R15
R14
N
Alberta
ENVIRONMENT
TECHNICAL SERVICES DIVISION
HYDROLOGY BRANCH
SUBMITTED A DE BOER, P ENG
DATE MARCH 4, 1982
APPROVED J CARD, P ENG
DATE MARCH 4, 1982
DESIGNED G W GUENTHER
CHECKED A DE BOER
DRAWN V DA SILVA
CHECKED G W GUENTHER
ATHABASCA AND McLEOD R. HEADWATERS
LOCATION MAP - HYDROMETRIC STATIONS,
SUB-BASINS AND COAL MINES
SCALE AS SHOWN
DATE MARCH 4, 1982
FIGURE No. 4-1

TABLE 4-2

ANNUAL MINIMUM DAILY DISCHARGES

McLEOD RIVER HEADWATERS

Exceedance Probability (%)	07AF002 McLeod River above Embarras River	07AG003 Wolf Creek at Highway 16	07AG001 McLeod River near Wolf Creek
	Annual Minimum Daily Discharge (m^3/sec)		
.01	2.72	0.878	7.82
.10	2.04	0.481	5.21
.50	1.25	0.170	2.83
.90	0.595	0.028	1.33
.99	0.227	0.000	0.623

4.2 Flood Frequency Estimates

Flood frequency estimates for the study area are also presented to illustrate how both climatic and physiographic factors influence peak flood flow rates. Table 4-3 summarizes the annual maximum instantaneous peak flow rates, based on the Pearson Type III frequency distribution, at three locations in the study area.

TABLE 4-3

FLOOD FREQUENCY ESTIMATES - McLEOD RIVER HEADWATERS

Exceedance Probability (%)	Return Period (Years)	07AF002 McLeod River above Embarras River	07AG003 Wolf Creek at Highway 16	07AF005 Eunice Creek near Hinton
.01	100	0.530	0.333	0.748
.05	20	0.327	0.217	0.485
.20	5	0.163	0.118	0.264
.50	2	0.069	0.054	0.124
coefficient of variation (std. dev./mean)		1.0	0.9	0.9
drainage area (km^2)		2560	829	17.1
period of record (years)		1955-1980	1955-1980	1968-1980

Both the McLeod River above Embarras River and Eunice Creek near Hinton share similar climatic and physiographic characteristics. Eunice Creek is a sub-basin within the McLeod River basin and is located near the center of the area contributing to the flow at station 07AF002 - McLeod River above Embarras River. A comparison of the flood frequency estimates at these two locations shows that the small drainage basin (Eunice Creek) exhibits higher peak flow rates than the large drainage basin (McLeod River). This behaviour is common in a hydrologic homogeneous region where large drainage basins generally show prominent channel storage influences while small drainage basins are generally sensitive both to high intensity rainfalls of short duration and to land use.

The two large sub-basins within the McLeod River basin (McLeod River above Embarras River and Wolf Creek at Highway 16) also exhibit significantly different peak flood flow rates. A possible reason for this difference is non-homogeneity between these drainage basins. For example, Table 4-1 shows that for an exceedance probability of 0.50 (a value near the mean) the runoff depth for McLeod River above Embarras River (231 mm) is 75 percent larger than the runoff depth for Wolf Creek at Highway 16 (132 mm). It may be concluded that the amount of precipitation over these two drainage basins differs significantly and therefore these two drainage basins are expected to exhibit different runoff characteristics. However, a comparison between the two basins may be valid for a specific runoff event if similar hydrometeorological conditions are shared for this event.

5. STUDY FINDINGS

The following generalities pertain to the hydrology of the pre-mining landscape in the east slopes foothills zone of Alberta:

1. this is a zone of rapidly changing climatic and physiographic conditions; therefore, the factors which influence runoff should be carefully considered when transposing data from a gauged watershed to determine runoff characteristics for an ungauged watershed,

2. high annual runoff volumes are measured in this zone and the water supply is sufficient to meet anticipated demands; however, offstream storage during low flow periods may be required to meet the water demand and the amount of storage required will be dependent on the location of the diversion and the instream flow requirements at the diversion point.

SESSION I - SETTING

Hydrology of the Pre-Mining Landscape, Andy DeBoer, Environment

M. TRUDELL

Can you give an idea of what component of Eastern Slope stream discharge is made up of groundwater flow?

A. DeBOER

Offhand, no.

P. ZIEMKIEWICZ

For any given watershed, how intensively does it have to be sampled to provide reliable estimated stream flows? Is the estimate particular to your watershed or can it be applied to other nearby watersheds? If so, what parameters have to be in common?

A. DeBOER

I think is is possible to extrapolate as long as the significant parameters: climatic and physiographic characteristics are similar.

T. SNEDDON

Is there any place in the Eastern Slopes where rapid transpiration exceeds precipitation?

A. DeBOER

No.

OVERVIEW OF MINING IMPACTS

By
D. Beddome, Alberta Environment, Land Conservation & Reclamation Council
K. Wheat, Alberta Energy & Natural Resources, Alberta Forest Service

ABSTRACT

The planning, operation and reclamation of a mine on the Eastern Slopes has an impact upon the hydrology of the area and it is hoped that this presentation will give an indication of some of the problems which can be encountered.

INTRODUCTION

During the course of mining, an individual act of a seemingly small nature may not seem very important, however, it is the number of mishaps over which we have the concerns and it should also be noted that in some instances, the problem only happened the once and was corrected. Because of this documentation, hopefully, the same problem will not happen to someone else in the future.

EXPLORATION

The time of year in which a program is being conducted cannot always be counted on to be condusive to operations. Due to variable conditions such as late approvals, changes in weather, budget restraints, etc., a program can run shorter or longer than initially planned. It is to these factors that initial planning should be done.

Proper preparation of the access road must take into account everything. The small drainage which appears to be a minor crossing may well be the major problem during spring break-up. Proper ice bridges or other crossings should be constructed to withstand a possible program extension into spring break-up. The crossing that breaks up can only cause more delays when time could be of the essence.

Fording of a watercourse is sometimes done. In dry weather or where traffic is minimal, the impact is not as great as when weather conditions change. At these times, the program will have to be shut down until conditions improve. A proper crossing could have eliminated the shut-down and may have allowed the program to be completed on time and under budget.

The inexcusable fact of the cat skinner pushing dirt across a watercourse for access is no longer acceptable. They are only following orders and in the future, these instances will be dealt with in a severe manner.

The proper method to cross a stream with causing minimal impact is with the use of a portable bridge. The bridge can be swung across the creek with the use of a backhoe thereby eliminating any bank disturbance. The placing of rip-rap on either side of the bridge reduces the churning of the soil and the carrying of dirt by tires onto the bridge which can then be washed into the creek during wet conditions.

Site preparation for the rig should also take into account if a sump will be required. A knowledge of the area hydrology often indicates the size required. Based on the terrain, a properly sized and constructed sump will do its job properly and effectively.

In the low, wet lands it may not be feasible to construct a sump. In this instance, the use of straw bales can be used to contain the cuttings and aid in the filtering of the water.

An instance we don't like to see is when the downhole water is not being controlled and the sump is trenched to allow for the release of dirty water and coal fines. Under these circumstances it is expected that corrective measures will be taken on the company's own initiative rather than being told to do so.

The use of foam as a drilling medium is sometimes used. This is generally a non-toxic Bariod foam if used according to directions. A retention-time of nine hours is generally recommended before it is rendered non-toxic. This means some method of control such as a sump is still required and not the immediate release into a possible drainage which could lead to a watercourse.

In certain areas a sump is not necessary if drilling without the use of additives. A small holding tank is sufficient to collect the cuttings and the drill water will not immediately be entering a watercourse. In these cases ground water is not a problem or drill holes are shallow.

Once a site is drilled, reclamation work should be done as soon as possible and not left until a later date. If flowing holes are evident, these are to be plugged immediately or mudded-up to control flow while drilling. The continual flow could result in future erosion problems or a cratering effect.

The initial clearing of the site also has a direct impact on the erosion potential. Extra clearing done over the side of a hill only makes for extra work and future erosion problems.

Leaving roads open for future programs often perpetuates problems. Seeding alone is often not sufficient and diversion ditches are still required for water control.

CONSTRUCTION

A mine is approved and major road building to the mine site is underway. Existing access is straightened and widened. The establishment of a road adjacent to a river is bad enough without being constructed right on a bend where future erosion by the river can definately be expected.

Even with the use of heavy rip rap to reduce the cutting by the river, the continual silt load from the road and the safety factor of vehicles leaving the road should be a determining factor.

All equipment requires servicing and the oils should be collected and properly disposed of. The allowing of oils to be drained alongside a stream gives indication of the environmental concerns of a company.

Proper culvert sizing and placement is crucial to minimize stream siltation and maintenance costs. The final end result of the road should be known to reduce the repetitive disturbance of a streambed to firstly install a temporary crossing and then installing the permanent one. This depicts a very poor review process from the company as well as the approving agency.

BEDDOME - WHEAT

Instability problems can be experienced when a road is built close to a river. It's easy to pin the blame on a consultant but that does nothing to reduce the impact of the failure. Corrective measures can always be done "after the fact" to reduce future problems, however, these should not have happened in the first place.

Settling ponds are a integral part of the construction process. It should be noted that approximately 70% of the siltation of any watercourse occurs during the first two years of development. It cannot be stressed enough that the construction of these ponds must be in place prior to any disturbance. Lack of space is not an acceptable excuse and better planning should be done.

The control and handling of water is a never ending problem, even after the system is in operation. A plugged culvert during a period of heavy rainfall can rapidly lead to problems. The addition of surface runoff water to sewage lagoons can cause them to fill and overflow. This not only results in erosion of the structure but the flushing of untreated sewage into the water system.

MINING

The actual site disturbance of mining effects the surrounding environment. An area is chosen for a pit and it seems that one of the prerequisites for viability is that it must be situated as close as possible to a river or lake.

Water at the coal seam is quite often evident and it is here where proper handling of the water is required. If the water is not handled and the equipment is allowed to operate through it, the result is an increased silt load to the settling pond and if the pond is unable to handle it, it flows straight on through into a watercourse.

Sometimes, due to operation failures or other factors, control of the water is not always done properly. Some failures can always be expected during a crucial time resulting in a movement of material. This water-saturated material once it starts moving moves swiftly and through anything and generally stops when it hits a creek.

Numerous questions often result from the nature of this type of incident. Who is responsible? Should it have been detected before it happened? Is it to be cleaned up, reclaimed or left? Who decides? What is learned? etc.

Haul roads for the large heavy haulers must be kept in good condition. When a company resorts to the use of breaker reject as a gravel during winter conditions, the effect of this is evident during spring break-up. This material readily breaks down under traffic and is washed away during spring rains. A disregarded request for settling ponds resulted in a concentration of 47,000 ppm entering the river.

During wet conditions the haul roads become slick and the top layer of road is often bladed to the side. This material is then washed by rainfall into the ditches which in turn drain into streams resulting in a silt accumulation of several inches over the winter ice. This material must be removed and precautions taken to prevent further occurances. The re-occurance of this situation does nothing for the rehabilitation of the stream.

BEDDOME - WHEAT

Improper drainage at the base of a dump can result in problems if not looked into immediately. Saturation of the base can result in the foundation slipping and the dump itself moving. In other instances when mining occous at the base of a hill, top slumping into the pit should be expected.

Even after reclamation has been completed, stability is still a problem. The reclaiming of slopes to natural contour is not always right if proper measures are not taken to control the water. A low spot in a road can cause water to collect and saturate the soil or water seepage becomes evident and slumping results.

SETTLING PONDS

When any type of major disturbance is to be done, settling ponds for the treating of dirty water as a result of the disturbance are required to ensure optimum water quality. The pond should be designed in such a way to do its job efficiently and with minimal maintenance problems. By maintenance we mean erosion of the inflow and outflow ditches, erosion of the dam structure itself and by dredging once it's capacity has been reached.

A good pond takes into account accessibility, ground conditions, structures, amount of area, proximity to the work area and the final outflow to the watercourse.

The inclusion of a small pre-settling pond results in reduced maintenance costs. The pre-settling of the larger particles extends the pond life, the smaller pond can be easily dredged, breaks the continual flow of water which improves the settling of particles.

A pond which is located to close to a watercourse invites problems to happen. The river, over time, can erode away the bank and eventually pose a stability problem to the pond structure.

A well planned pond system depicts a small pre-settling pond overflowing into the larger pond. The outflow is not situated in a direct flow line with the inflow which helps reduce the flow velocity. Access is available completely around the pond should dredging be required. The outflow is channelled into an existing drainage course thereby reducing another entrance to the river.

The use of decant towers enables a better control of water flow from the pond during periods of high or low rainfall. The tower must have a solid foundation and the outflow pipe should be straight with minimal bends. The foundation is susceptible to constant water flow and eventual eroding of the base can be expected over a period of time. Reducing the number of bends in the outflow culvert simply reduces the number of joints which are weak points and ensures a smooth, steady release of water.

This smooth flow of water should be released into the spillway with no drop for the outflow pipe. If it is not properly installed, severe erosion can result which only leads to extra work.

The spillway should be properly constructed to handle the flow of water and minimize erosion of the channel. The use of a plastic liner, rip rap or filter cloth reduces the cutting action of the water and proper backsloping and seeding will ensure minimal siltation from banks.

Extra work is required where steep grades and long distances cause the water to be released at high velocities. These instances are more the exception than the rule and done properly, cause minimal maintenance problems which would be excessively costly in these cases.

The quality and quantity of water the pond will be expected to handle must be known. Water from underground workings is certainly different from that of open pit. The use of flocculents to increase the settling rate is required when the particles are too fine to settle on their own.

Ponds which are handling water from maintenance shops, etc., should have booms and absorbants readily available in the event of oil spillages, etc., to ensure all surface pollutants are collected before being released.

The ponds themselves are only as good as the ditches that feed them. If the ditches are constructed through erodable materials then naturally problems will be encountered. The solution then is to make the channel as permanent as possible which will in turn save dollars on maintenance of both the ditch and the cleaning costs of the pond to remove this additional material.

In terrain where ditches cannot be utilized, open chutes or half culverts are sometimes used and some problems are experienced with the amount of ice accumulation during the winter. This could be attributed to the fact that the top is open and snowfall may have an impact on the amount of ice build up which often reduces the efficiency of the chute. With the structure filled with ice, the water overflows the confines of the chute and can result in erosion which may have a detrimental impact to the structure.

During a storm period which was classed as 1:10 year storm, the following occurred:

1) Ponds silted up completely and water flowed over the dam. Some of these ponds were constructed in a valley utilizing the hills as walls. This may have been a good idea at the time, but now, how do you get around the pond to dredge it out?

2) The spillway of some ponds consisted of a half-culvert which was able to handle normal flows. Under flood conditions and perhaps a slight bend in the culvert or not being securely fastened, water overflowed the edges thereby resulting in erosion and damaging of the structure.

3) Other ponds were silted to capacity and the water flowing over the dam simply eroded away the entire structure.

Whether the settling pond weathered the storm or not, maintenance in preparation of future storms must be done. Different methods are used for dredging of these ponds of which using a crane is one. For this method access is required around the entire pond and the pond must be small enough to enable the crane to reach half way across.

Arrangements must be made to handle the incoming water during the time dredging is underway. If this is not done, the result is a soupy mixture which is very difficult to load, transport and dispose of to say nothing of the quality of water which is being released during this operation.

Winter conditions can cause additional problems dependent upon the volume of water going through. It is during these months that the decant towers must be closely monitored to ensure that a buildup of ice is not occurring and interferring with release capacity of the tower.

A pond which has sufficient volume to retain a liquid space under the ice is able to work properly. On the other hand, however, if there is not enough water flowing into the pond, the entrance of the pond freezes causing the water to flow over the ice instead of under. The water then simply flows through the system and onto the river ice.

The immediate solution is to drop more boards into the decant tower to increase the retention time. This in fact does more harm than good. This then causes the water to freeze which builds up the ice layer which, if done all winter, makes the pond solid ice. Come springtime when the pond is needed most, the pond is inoperable until July when the ice is gone.

TAILINGS PONDS

As most prep plants are designed as close circuit systems, the tailings ponds are an integral link in the handling of the slurry. In some cases, it's been noted that these ponds are often operated at full capacity with insufficient freeboard should there be an emergency.

The transportation of slurry to these ponds is done by pipeline and usually for some distance. Because of human error or mechanical breakdowns, the flow of this slurry is sometimes intercepted resulting in the free flow into drainages which may or may not end up in settling ponds.

Pipelines are not the only area where problems can be experienced. Because insufficient background data is used when constructing the tailings ponds, later information on coal seams can often result in mining adjacent to pond walls. This in turn causes instability and leaks. This dirty water rather than being pumped back into the slurry pond is routed into settling ponds which are not designed for this.

Intermediate measures can include the excavation of pre-settling ponds for which equipment and manpower are not always readily available on these emergency situations.

This discolored water which can be within the approved operating guidelines of 50 ppm is released from the settling ponds under standing legislation and is allowed to enter into major watercourses. This causes numerous complaints by the public using the area for recreational purposes.

UNDERGROUND MINE

Underground mining also has an impact on the environment with considerally less surface disturbance. However, coal seams are famous for ground water and can cause severe water management problems. These problems continue even after mining has been completed when water is allowed to enter old workings depositing iron or sulphur into watercourses.

RECLAMATION

Water problems are not eliminated once mining is completed and reclamation is of prime importance in water management. The ability to properly control and manipulate the surface waters to the best advantage goes a long way in the reduction of the mining impact upon the terrain.

Overview of Mining Impacts,
D. Beddome, Environment
and
K. Wheat, Alberta Forest Service

L. BROCKE

Is it your contention that the settling ponds being put in place and utilized in the mountains and foothills are too small?

K. WHEAT

Yes - they should be designed larger. Last year alone we had 78% over normal rainfall.

L. BROCKE

They are designed now for a 1 in 10 year, 24 hour event. There is some push now, south of the border, for a 1 in 100 year, 6 hour rainfall in design criteria. I wonder what this would do to sizing. Maybe one of the hydrologists can comment?

G. BECKSTEAD

1) This (1-10) is only a guideline. Anyone is allowed to exceed that if they feel it is in their own best interest.
2) It must be realized that it is only a value of precipitation and density that you are being asked to design the pond for. No one has talked yet about how much snow melt is going to occur in runoff.

S. MORAN

Presumably, you are loading sediment at a rapid rate, which changes your volume significantly. What percentage of under-design are you seeing?

D. BEDDOME

We have three settling ponds which are over-designed and are therefore giving us no problems. The others - approximately 80% are under designed.

R. MILLSON

It appears that we are having a 1-10 year cycle more frequently. Does this reflect a cycle within the hydrological cycle or does this reflect that our rain data is not sufficient in the mountains and foothills?

S. MORAN

One comment - It may very well be that we are in a period of climatic change.

L. JACKSON

It appears that you can only take the climatic data so far - and with the shortness of our records, it is difficult to determine how reliable our data is for projecting into the future.

Implementation of a Water Management Program,
K. Crane, Luscar

L. JACKSON

The problem seemed to be with suspended sediment - it is a cosmetic problem - if it doesn't settle on the pond, it's not going to settle in the stream. Does it bother the fish?

K. CRANE

That we don't know. It certainly bothers the fishermen. It is hard to accept visually, yet the tests we ran, as well as tests done by Alberta Environment, show that within the suspended solids count, we were okay, but there was no standard guideline for turbidity. We've now got 7 or 8 different ponds to sample and specifically treat , it looks like we are going to have to look at a different flocculant than we have been using. It took the problem to arise to cause us to do that because for the first 3 or 4 years, the flocculant worked fine. Hopefully, that will be the answer to the clouding problem we had this year.

R. MILLSON

This clouding problem is due to tailings water getting into this pond, is it not?

K. CRANE

Yes.

R. MILLSON

I hope you take the approach of removing your tailings water from the other drainage system.

K. CRANE

That is still the intent. Once again, there is no easy answer. There are 7 1/2 million dollars worth of filter

presses not working right yet. Nobody anticipated tailings running into the pit. At least if we can treat the tailings water in place to make it clearer we will be ahead. So far this year, the flocculants we were using haven't been doing the job - where they had worked in the past. Hopefully, next year the filter presses will be doing their job. The thing, is the systems are being put in. The money is being spent and there is a standard of doing the job once and doing the job right.

SESSION II - REGULATIONS

The Fisheries Act,
Alan Locke, Fish and Wildlife

G. BECKSTEAD

What sort of penalties are being levied?

A. LOCKE

Usually, penalties levied in Alberta are minimal.

P. ZIEMKIEWICZ

Who ultimately decides if a case will be brought to court?

A. LOCKE

The regional Fish and Wildlife staff.

HYDROLOGIC RESEARCH IN THE EASTERN SLOPES

by:

Glen Bergstrom
Alberta Forest Service

I am pleased to present this short paper to you as persons concerned about the environmental well being of our province. It is my desire to help increase your appreciation of the eastern slopes in terms of water production and some of the physical reactions we are likely to encounter when the eastern slopes are disturbed.

The approach that I would like to take in presenting this paper is to first look at the role of the eastern slopes in water production and the government's position in terms of their protection. Secondly, I will present some of the research work that has been or is being done in Alberta on the eastern slopes and then conclude the paper with a brief discussion on some management implications.

HYDROLOGIC VALUE OF THE EASTERN SLOPES

Although the eastern slopes have been recognized for their value in water production since the early 1900s, it was not until 1947 that a formal agreement was signed between the Federal and Provincial Governments to jointly manage the headwaters of the Saskatchewan River Basin for optimum water production in terms of quality, quantity and timing. Alberta's concern, in part, was to provide enough water for the water deficit region of southern Alberta, while the Federal Government's concern, in part, was fair apportionment for inter-provincial water consumption. When the agreement finally expired in 1982, Alberta had assumed full management responsibilities and a formal apportionment agreement had been reached between Alberta,

Saskatchewan and Manitoba on a fair and equitable distribution. Thus, hydrologically speaking, the eastern slopes has a significant impact not only on Alberta, but also on Saskatchewan and, to a lesser extent, Manitoba.

Within Alberta, the vital role of the Saskatchewan River headwaters is illustrated by the fact that 88% of the water available in the prairie region is produced from a region of the eastern slopes about 12% the size of the prairie region.

The hydrologic value of the eastern slopes is also shown by on-site demands. Some of the most spectacular outdoor recreational areas in the world are part of this region. Good fisheries and wildlife areas abound. Range management has become an integral part of the management scheme.

In addition to water production, the eastern slopes are also important for timber production and as a storehouse for natural gas, oil, coal and other minerals. Because of the government's commitment to the multiple land use concept, integrated management plans are developed to make best use of these resources.

In the past, the abundant supply of clean water was often taken for granted. However, the expansion of agricultural activities in the water deficit areas of southern Alberta, necessitating more and more water consumption through irrigation, has brought into sharp focus the limited amount of water naturally available to this region.

Because of the essential nature of the eastern slopes to provide water for our water deficit regions, the government has made watershed management (the management of the watershed to provide a reliable and adequate supply of clean water for on-site and downstream use) the number one priority for this region. This, of course, does not preclude land use activities from being carried on. Rather, by designating watershed management as the number one priority, the

government is saying that where conflicts arise between watershed management objectives and land use activities, watershed management concerns would be met first. This was clearly brought out in the Government's 1977 A POLICY FOR RESOURCE MANAGEMENT OF THE EASTERN SLOPES.

To ensure effective watershed management, guidelines and regulations were developed. Unfortunately, the lack of an adequate inventory base regarding streamflows, suspended sediment levels in streams, soils, climate and geology, particularly at the subwatershed level, precluded effective protection of some of the more sensitive areas in the province. The guidelines developed were often too general and, therefore, did not adequately address regional concerns.

Over the past five years, the Alberta Forest Service has placed three watershed foresters in three eastern slopes Forests (Bow/Crow, Rocky/ Clearwater and Grande Prairie). Our inventory base is slowly building. As a result, we hope that we will soon be able to modify, where necessary, those guidelines to make watershed management more regionally effective.

The Alberta watershed research program to date has contributed little to helping establish more effective guidelines or regulations. One of the basic problems has been the lack of direction given by the manager to the researcher indicating what, in fact, the needs are. We are hoping that the recent establishment off our own Alberta Forest Service Research Branch will provide answers not available simply through inventory work.

HYDROLOGIC RESEARCH IN ALBERTA

A common objective of all research studies in Alberta has been to determine the effects of vegetation manipulation on water yield. Studies throughout the United States and world have shown that, at

least at the subwatershed level (up to 25 square kilometres), significant increases in water yield have occurred through timber removal.

Table one shows the research programs that have been or are currently underway and some of their results. The Marmot Creek study, consisting of three subwatersheds, was set up to evaluate the effect of timber harvesting in sub-alpine areas on streamflow. One subwatershed underwent a normal commercial cut, while the second had a series of small circular patch cuts done on it. The adjacent third subwatershed acted as the control. A 12-15% increase in streamflow was detected from the commercial cut watershed. The results from the patch cuts have not yet been fully analyzed. One interesting observation from the commercial cut was that water quality in terms of inorganic sediments was unaffected. The roads and landings were carefully laid out, resulting in no significant input of sediments.

The Streeter Creek subwatershed was patch cut to increase the snow accumulation and ultimately, the runoff in an aspen parkland setting. The study was successful in increasing annual flows up to 50%. The significance of this study was that higher than expected flows occurred during the late summer and fall, indicating that significant amounts of the surplus water were being added to deep storage supplying the base flow.

The Tri-Creeks watershed study was set up to determine the impact of commercial timber harvesting operations in a lodgepole pine forest on the chemical, physical and biological characteristics of two foothills trout streams. One subwatershed has been cut with riparian vegetation left in place. In the other subwatershed, no riparian vegetation along the cutblocks was left. The results to date are inconclusive. With almost 50% of the merchantable timber harvested in the Wampus subwatershed, a cursory look at the data shows no significant increase in flows. These results are interesting in view of Swanson and Hillman's (1977) study in the same region indicating a 27% increase in streamflow of nine logged subwatersheds compared with nine similar unlogged subwatersheds.

TABLE 1

Watershed Research Activity in Alberta

WATERSHED	PURPOSE - OBJECTIVES	CALIBRATION PERIOD	TREATMENT PERIOD	RESULTS
James River	To determine snow trapping efficiency and ablation rates in circular openings of 1/4 to 6 tree heights (H) in diameter spaced 10 H between centres.		1973-1976	1. Greatest accumulation occurred in 2H to 3H openings. 2. Rapid drop off in accumulation rates below 3/4 H openings. 3. Ablation rates least in 1 H openings. 4. Ablation rates greatest in 5H-6H openings.
Marmot	1. Determine the hydrology of the basin with particular reference to the inter-relation of precipitation, streamflows and groundwater. 2. To determine the effect of commercial timber harvest and subsequent regrowth in subalpine spruce-fir upon the hydrology of the area. 3. To develop methods and to determine the effects of purposive manipulation on high-elevation, non commercial spruce-fir forests upon water yield and regime.	Cabin Creek 1963-1974 Twin Creek 1965-1978	Cabin Creek 1974 Twin Creek 1979-1980	Cabin Creek 1. Showed about a 1 inch (12%-15%) increase in runoff. 2. No problems with sediment in streams when guidelines followed. 3. No channel degradation noted with increased streamflow. Twin Creeks Results are still being analyzed.

WATERSHED	PURPOSE - OBJECTIVES	CALIBRATION PERIOD	TREATMENT PERIOD	RESULTS
Sring Creek	To determine the quantitive changes in hydrologic character as virgin woodland was converted to agricultural use. The treatment will inclyde the conversion of 12 mi^2 of a subwatershed in Upper Spring Creek to grazing land.	1966-		No results are available as land conversion has not yet taken place.
Streeter Basin	To determine the hydrologic and range productivity effects of aspen removal and subsequent conversion to grassland. (One of the efforts was to keep snow on the upper slopes for a longer period of time into the spring.)	1963-1976	1976-1977	1. The springs being measured showed about a 50% increase in discharge. 2. In 1977, the second driest year on record, the spring did not dry up as predicted. 3. More wildlife observed. This is perhaps because more openings made them more visible.
Tri-Creeks	To determine the impact of timber harvesting operations in a lodgeople pine forest on the chemical, physical and biological characteristics of two foothills trout streams.	1968-1978	1979-1983	No results are yet available as the treatment phases in Wampus and Deerlick Creeks are not completed.

While these results from the Alberta scene verify results from abroad, the problem of confidently predicting how much of a water yield increase we can expect still remains. Swanson and Hillman (1977) found large variations in both the logged and unlogged basins. Models and procedures are being developed to predict expected yield increases. Currently, the Alberta Forest Service is working with a procedural manual developed by the United States Department of Agriculture (U.S.D.A.) called Water Resources Evaluation of Nonpoint Silvicultural Sources (WRENNS), which is used, in part, to estimate the extra amounts of water potentially available to streamflow when timber harvesting occurs. Work to date has been positive and we are expecting it to be a valuable management tool as it becomes better calibrated to Alberta conditions.

The James River study was set up to determine snow trapping efficiency and ablation rates in circular openings, ranging from 1/4 to 6 tree heights in diameter and spaced 10 tree heights apart. One aspect of increasing water yield is snow redistribution. Small patch cuts, circular cuts being the most efficient, act as traps for snow. These traps provide at least three functions: 1) they collect much more snow than the forested areas, 2) the ablation rates (the change of snow to water or water vapour) are reduced, and 3) the snowmelt period in the spring is stretched out over a longer than normal period of time. The results showed greatest snow accumulation in the 2-3 tree height (H) openings, with a rapid drop off in accumulation below 3/4 H. The greatest ablation rates occurred in 5-6 H openings. Ablation rates were least in the 1 H openings. These results are important if management for water yield improvement becomes a primary objective.

The Spring Creek Watershed Study near Valleyview was set up to determine the quantitative changes in hydrologic character of a virgin woodland converted to agricultural use. To date, no treatment has been carried out.

MANAGEMENT IMPLICATIONS

One of Alberta's primary water management problems is distribution. Approximately 6% of all the water leaving Alberta flows through the agricultural water deficit southern prairie region. The demand to put more land into agricultural production in this region, primarily through increased irrigation, is seriously taxing the already short supply available. Methods of improving the efficiency of water use are being developed. However, these can only be considered a stop-gap. Eventually the absolute supply of water will have to increase. Currently two alternatives are open to us: 1) inter-basin transfer, and 2) vegetation manipulation to improve water yield.

The concept of inter-basin transfer has been put forward a number of times in the past. The present Alberta Government maintains, however, that it will not be party to any water transfers until water within the transferring basin is being used to its maximum potential and water is available to be transferred. Based on this criteria, one would not expect inter-basin transfer between major basins to be a reality in the forseeable future.

As shown earlier, water yield improvement through vegetation manipulation, at least the subwatershed level, is a reality. The often heated discussion that follows is whether these results can be extrapolated to the larger basin. Research results indicate cutblock size and design is important to maximize snow catchment. Snow melt in these small cutblocks is delayed, but usually only up to about three weeks. Therefore, to make use of this extra water generated, storage facilities downstream will have to be put in place.

Water yield improvement through vegetation manipulation would also have a significant impact on a timber harvesting program. Using the small patch cuts would substantially increase logging costs as compared to the more conventional methods currently used.

Not only would logging companies be burdened with substantially higher logging costs, but the government would have to evaluate its whole policy of sustained yield management as it is practiced today. Currently, one percent of the merchantable timber volume is harvested yearly based on a 100 year rotation. Under a program to improve water yield through vegetation manipulation, a much larger portion of the forest base would have to be maintained in a harvested condition.

While the greatest negative impact of a water yield improvement would probably be felt by the timber industry, impacts on other land use activities such as recreation, grazing, gas and oil exploration and development and mining would also have to be considered. Depending on the management program embarked upon, the impacts could be negative or positive. For example, from a wildlife or grazing perspective, a large number of small patch cuts would be beneficial. On the other hand, increased flows could be harmful or helpful to the resource, depending on the timing and magnitude of the yield increases. Coal mining particularly the open pit method, is not compatible with a watershed management program to optimize water yield improvement.

Lastly, I would like to briefly address some of the hydrologic problems faced with coal mining, in particular, open pit mining. Perhaps the most distruptive element from a hydrologic perspective is the destruction of surface and subsurface flow patterns. Open pit mining must, of necessity, remove massive amounts of overburden to get to coal seams. In so doing, surface and subsurface flows are often destroyed or drastically altered. Perched water tables can also be destroyed or altered to such a degree that streams being fed from these sources change drastically or dry up. Soil disturbance and compaction from mining activity will affect infiltration and percolation rates, which in turn can significantly affect the magnitude of peak flows and substantially alter the flow regime.

The quality of the water is also affected. Sediments from the exposed mineral soil and the processing procedures inevitably work their way into systems draining the lease area. Settling ponds and flocculation

stations are used and are successful up to certain level, but much fine material still escapes and passes on into water systems outside the lease. The magnitude and type of sediment passed out will have varying degress of negative impact on the aquatic biological communities.

Comparing underground mining to open pit mining, the effects on the hydrology would be greatly reduced. Underground shafts will disrupt some subsurface flow patterns, but primarily, only those the shaft would directly intercept. The important thing is that the topsoil remains intact, permitting surface and most subsurface flow patterns to remain the same.

In conclusion, it must be remembered that trade-offs must occur between industry and the environmental ideal. What are we willing to give up or sacrifice to have something else? Mining operations such as open pit coal mining are often incompatible with the environmental conditions we would like to maintain. In the end, the political arm of the government will have to define what our priorities are and what trade-offs will be tolerated.

SESSION III - RESEARCH AND EXPERIENCE

Hydrological Research in the Eastern Slopes, G. Bergstrom, Alberta Forest Service

L. JACKSON

You talked about the problems of variability in watershed properties, specifically suspended sediment discharge in the basin. Has there been much discussion as far as people regulating or drawing up guidelines to a sliding scale for maximum allowable suspended sediments, so that what is coming out of the settling pond cannot actually exceed what is going on in the stream?

G. BERGSTROM

That is the problem we are faced with. It is almost impossible to set limits. Our approach is to try to work problems out with companies.

G. BECKSTEAD

One quick comment with respect to Marmot Basin and the effect of the increase runoff having no stream degradation. It may have to do with the timing of that runoff - as you said, with the logging operation prolonging the melt - that may, in fact, give you different peaks - not disturb the stream, but give you an overall greater flow volume over a year.

G. BERGSTROM

That could very well be.

G. HOLECEK

What would be the effect of increasing the runoff by 20% and delaying it by two weeks?

G. BERGSTROM

I alluded to that earlier: that water yield improvement is only a supplement to on or off stream reservoirs. If we can provide more water to be stored for use later on, that is good.

A SUMMARY OF WATER CHEMISTRY DATA FOR UNDISTURBED COAL-BEARING WATERSHEDS AND A SYNOPTIC SURVEY OF OPEN PIT MINE LEACHATES, SOUTHERN ROCKY MOUNTAINS, ALBERTA AND BRITISH COLUMBIA[1]

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Abstract

Surface water chemistry data were assembled from undisturbed coal-bearing watersheds located in the Rocky Mountain Foothills and Front Ranges of Alberta and British Columbia. Basins underlain by all three of the coal producing formations were represented in the compilation. Stream water chemistries reflect the abundance of carbonate minerals in bedrock and overburden. Waters are alkaline and are dominated by calcium, magnesium, and bicarbonate ions; sulphate may also be an important constituent. Toxic trace elements are well within acceptable limits for drinking water except for local occurrences during winter months. Phenols may regularly and naturally exceed Environment Canada water quality guidelines for the protection of aquatic life.

The chemistries of leachates emanating from orphaned coal mine wastes were determined for twelve sites representing the three coal-bearing formations found in the Foothills and Front Ranges of Alberta and British Columbia. Leachates were generally alkaline. Those sites with slightly acidic leachates drained predominantly coal wastes. Calcium and magnesium were the dominant cations and bicarbonate was the dominant anion at all sites. Luscar Formation and "Coalspur Beds" leachates were richer in sodium with respect to Kootenay Formation leachates. Conversely, Kootenay Formation leachates were richer in sulphate content with respect to the leachates of the other two formations. Only the concentrations of iron and manganese regularly exceeded permissible guidelines set by Environment Canada for drinking water and the protection of aquatic life. No harmful organic compounds were detected.

Introduction

Water pollution has been and still is one of the most chronic problems associated with coal mining and overburden waste disposal over much of eastern North America and western Europe. With increasing production of coal in the Foothills and Front Ranges of the Rocky Mountains of Alberta and British Columbia by open pit methods in late 1960s and early 1970s, public concern was directed to the possibility of widespread water pollution in these areas. Little hard evidence existed at that time to determine if this fear was well founded.

In examining the environmental impact of coal resources development in this region, I have had the opportunity both to assemble available water chemistry data for undisturbed coal-bearing areas and to carry out a synoptic sampling of leachates emanating from orphaned open pit workings. It was my hope that this data would indicate what, if any, water pollution problems might accompany the long term weathering of coal overburden wastes.

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[1]This paper is abridged from a slightly longer paper previously published in Current Research, Part B, Geological Survey of Canada, Paper 82-1B, p. 239-251, 1982.

The Canadian Rocky Mountain Foothills and Front Ranges form a long narrow belt stretching from southwestern Alberta and southeastern British Columbia, northwest to northeastern British Columbia (Fig. 1). The Foothills are composed of northwest-trending folds and thrust faults of Mesozoic and lower Cenozoic clastics. Surface elevations range from about 1000 m in the Foothills to almost 3000 m in the Front Ranges.

Two distinct structural belts have yielded coal within the Rocky Mountains and Foothills. From west to east they are the inner Foothills and outer Foothills (Latour, 1972). In the outer Foothills coal production has been principally from the Upper Cretaceous "Coalspur Beds" (MacKay, 1949) in the Coal Valley and Saunders areas (Fig. 1). This unit outcrops in a narrow belt between the North Saskatchewan and Athabasca rivers. The coal produced from this area is typically high volatile bituminous in rank. Although the coal-bearing units within this belt have been folded and faulted, relative relief is low, generally less than 200 m. The inner Foothills belt extends westward to the mountains and includes parts of the Front Ranges. Within the belt are major folded and faulted structures which are expressed as high ridges which persist for many kilometres. Relative relief generally ranges between 500 and 1000 m. Coal producing formations are Lower Cretaceous in age. South of Red Deer River, the Kootenay Formation produces coal, whereas to the north of it, the Luscar Formation is productive. Coal from the inner Foothills belt is low to medium volatile bituminous in rank.

Bedrock and Regolith Chemistry

The inorganic water chemistry of the streams draining the coal belts of the Canadian Rocky Mountain Foothills is largely dictated by the chemistry of the bedrock and overburden materials. Equally important, the chemistry of these rocks and overburden materials determines changes in water chemistry when they are disturbed and exposed as rock wastes during and after the mining process. Analysis of bedrock chemistry has only been carried out at a few sites within the coal belt-typically as a part of environmental baseline studies. Values for samples from representative cores from the Kootenay and Luscar formations, and "Coalspur Beds" are presented in Table 1A; the table is not intended to be a complete summary of bedrock chemistry data but rather an indication of the ranges of values found within a single section or a cluster of closely spaced sections or mine dumps.

General observations can be made based upon the data in Table 1A. First, the Luscar Formation and the "Coalspur Beds" contain significant sources of soluble sodium whereas the Kootenay Formation does not. The sources of this sodium are sodic shale beds which represent a significant thickness of the "Coalspur Beds" but are thinner and of less significance in the Luscar Formation. Secondly, soluble carbonate is present in all three formations; the source of the carbonate are carbonate minerals which form the cementing media in associated sandstones. Thirdly, all the units are low in sulphur; sulphur is in the form of pyrites in the Kootenay Formation and is present in organic compounds in the Luscar Formation (Weyer and Vonhof, 1980). The form of sulphur in the "Coalspur Beds" has not been established.

Inorganic regolith materials can be subdivided into two general classifications: colluvium, which encompasses disaggregated sediment formed in place or transported only a short distance from its parent bedrock, and glacial till. Unlike colluvium, the composition of till is influenced to varying degrees by all the rock that the glacial ice traversed. Table 1B details the chemistries of till and colluvial sediments from coal producing areas of the Foothills and Front Ranges. High pH

Figure 1. Reference map showing locations of the orphaned mine sites studied as well as locations of stations monitored for pristined water chemistry.

nec - water chemistry stations operated by the British Columbia Ministry of Environment (BCME) in the northeastern coal block; s - Grande Cache area studied by Hackbarth (1979); m - Tri Creek Basin, Cadomin, and Mountain park area; x - Marmot Creek Experimental Watershed; e - upper Elk River basin; q - Cabin and Howell Creeks BCME water chemistry sties; c - Coal valley area; n - Nordegg area; g - Grassy Mountain Mine; t - Tent Mountain Mine; y - York Creek Mine, Crowsnest River.

TABLE I

A. Soluble major cations and anions and miscellaneous chemical parameters of crushed rocks from coal-bearing sections, Rocky Mountain Front Ranges and Foothills, Alberta

Formation	Sample section thickness (m)	Number of samples	pH	Conductivity (millimhos/cm)	H_2O Soluble (Meq/L)* Ca	Mg	Na	K	HCO_3^-	SO_4^{-2}	Sodium absorption ratio	Total sulphur (ppm)
Luscar[1]	160	41	9.6 6.4	2.0 0.27	7.02 0.16	7.02 0.12	20.49 1.49	3.21 0.10	17.2 0.0	12.13 0.53	53.9 0.7	8415 237
Coalspur[2,3]	10	7	7.6 4.0	1.50 0.14	1.91 0.21	0.37 0.08	22.4 4.13	0.38 0.09	10.5 2.5	30.2 2.25	39.3 7.3	534 149
Kootenay[4]	Not Available	6	8.2 7.5	2.3 0.87	23.21 1.50	2.36 0.21	0.28 0.05	1.73 0.03	3.06 1.14	28.12 0.15	1.18 0.36	< 10 000[5]

B. Solumble major cations and anions and miscellaneous chemical parameters of inorganic regolith materials from coal-bearing areas of the Rocky Mountain Foothills and Front Ranges, Alberta and British Columbia

Location (coal-bearing) formation)	Number of samples	pH	Conductivity (millimhos/cm)	Ca	Mg	Na	K	HCO_3^-	SO_4^{-2}	Sodium absorption ratio
Luscar and Coal Valley (Luscar Formation[2,6] and "Coalspur Beds")	24	6.5 4.3	0.12 0.6	3.27 0.27	1.83 0.12	0.53 0.18	0.57 0.06	2.4 < 0.2	9.75 0.55	0.72 0.21
Crowsnest Pass and Elk Valley[5] Alberta and British Columbia (Kootenay)	9	8.2 5.1	1.95 0.08	18.46 0.25	10.20 0.04	1.04 0.05	0.18 0.02	3.06 1.14	28.12 0.15	0.64 0.07

*Where two values are given, they represent maximum and minimum

[1]Devenny and Ryder, 1977

[2]Luscar Sterco Ltd., unpublished data

[3]Samples obtained from three separate cores

[4]Unpublished data collected for this study from abandoned open pit dumps Crowsnest Pass area, Alberta and British Columbia

[5]Consolidation Coal, personal communication, 1978

[6]Luscar Ltd., unpublished data

values and relatively large values for soluble calcium, magnesium, and bicarbonate reflect the chemistry of tills in areas adjacent to the carbonate-rich Front Ranges. Those with acidic pH values and relatively low values for soluble calcium, magnesium, and bicarbonate reflect colluvial sediments developed upon noncalcareous shales and older tills that have been leached of carbonates. In general, glacial sediments containing calcite and dolomite are present in most valleys of the Foothills and Front Ranges as a consequence of former valley glaciers which advanced from the carbonate-rich Front Ranges during the ice ages.

Previous Work

Water Chemistry of Undisturbed Coal-bearing Areas

Although numerous streams are monitored for water chemistry in Alberta and British Columbia by federal, provincial, and municipal agencies and industrial firms, detailed water chemistry sampling of streams draining essentially unaltered basins predominantly underlain by coal-bearing formations is rare. Those basins for which data are available are typically either experimental watersheds or watersheds monitored by coal companies during the course of environmental baseline studies prior to mining operations.

Table 2 describes these basins. Their locations are plotted on Figure 1. Of these, only the upper Elk River basin, Flathead River basin, Marmot Creek experimental watershed, Tri Creek experimental watershed, and streams sampled by Hackbarth (1979) in the Grande Cache area provided significant enough quantities of data to merit compilation.[1]

Water Chemistry of Disturbed Coal-bearing Areas

Few past studies have dealt with changes in surface water chemistry specifically due to dumping of bedrock or overburden material in conjunction with open pit coal mining in the Foothills and Front Ranges of the Canadian Rockies. Etter (1971) analyzed water chemistry in three streams near the Cardinal River Mine. All streams sampled drained coal overburden dumps or areas disturbed by coal exploration activities. Measured concentrations of iron, dissolved solids, and alkalinity were well within the guidelines for drinking water. No values were available for nearby pristine streams for comparison. Root (1976) analyzed water from a variety of sites ranging from flooded pits to springs flowing from waste dumps at an abandoned open pit coal mine south of Cadomin, Alberta. One sample was obtained from each of six sites, including undisturbed drainage where it entered the waste dumps. Root found the chemistry of water in the ponds and springs to fall within the same range as water entering the dump. Concentrations of all cations and anions in the samples were within the standards for drinking water set by the Alberta Government. Harrison (1977) sampled underground mine effluent, pond water in flooded open pits, and springs below waste dumps in the Crowsnest Pass area of southwestern Alberta and southeastern British Columbia. Samples were analyzed for a number of physical parameters and major dissolved cations and anions. No attempt was made to compare analyzed values with surface streams except for qualitative comparisons of suspended sediment contents. Samples were not filtered in the field so that the values he reported for samples fixed with acid in the field measured extractable rather than dissolved concentrations. Harrison generally found little difference between pond, dump spring, and adit drainage in the area. Hackbarth (1979) monitored water

[1] As of December 1979 when this compilation was made.

TABLE 2

Sources of inorganic water quality data for coal-bearing terrain undisturbed by coal resources development

Location (cf. Fig. 30.1)	Stream Basin	Monitoring Agency	Station number of reference	Period of record and record quality
q	Flathead River basin, B.C.	B.C. Pollution Control Branch	B.C. Ministry of Environment, 1976a.	1971-1974; major and minor nutrients, toxic trace elements; 6-8 samples per parameter.
l	Elk River basin, B.C.	As above	B.C. Ministry of Environment, 1976b.	1972-1974; upper Elk River, sporadic sampling of total N, TDS, alkalinity, total P. 1973-1974; upper Fording River, sporadic sampling of major ions and traces elements . 6-21 samples per parameter.
e	Upper Elk River basin	Elco Mining Ltd.	Elco Mining Ltd. 1978 (unpublished)	1976-1977; major and minor nutrients, trace elements on a regular basis from Elk River, site specific sampling from smaller streams in the area.
x	Marmot Creek experimental watershed, Alberta	Environment Canada	00AL05BF0001 00AL05BF0002 00AL05BF0003 00AL05BF0004 00AL05BF0005	1963-present; major and minor nutrients; >200 samples per parameter.
m	Tri Creek experimental watershed, Alberta	As above	00AL07AF0001 00AL07AF0002 00AL07AF0003	1971-1975; major and minor nutrients; 20-25 samples per parameter.
s	Smoky River above Hells Creek	As above	00AL07GA0001	1970-1975; major nutrients; 43-48 samples per parameter.
s	Sheep Creek - Smoky River, Alberta	Meadowlark Farms Ltd. (1976), unpublished data	Numerous sites	1974; major and minor nutrients, toxic trace elements; about 10 samples per parameter.
s	McIntyre Mine area, Grande Cache, Alberta	Alberta Research Council	Hackbarth, 1979	1972-1978; major and minor nutrients, toxic trace elements; <12 samples per parameter.
nec	Peace River Coal Block, B.C. (Murray Wolverine, Sukunka, Narraway, Belcourt, and Wapiti River, and Pine River basins)	B.C. Pollution Control Branch	Stations 1177701-1177748	1976-present; major and minor nutrients, toxic trace elements; 2-21 or more samples per parameter.

chemistry changes in springs emanating from dumps at the McIntyre Mine near Grande Cache over a seven year period. He found that the yield of total dissolved solids progressively increased to a factor of four during the period of observation but that the ratios of cations to one another remained the same. However, some changes in the ratios of anions occurred: sulphate increased at the expense of bicarbonate and nitrate increased dramatically to levels well beyond those set for drinking water as the result of explosives residues. Nitrate values dropped rapidly, however, following the cessation of the dumping of recently blasted rock. The pH remained in the range of 7.6 to 8.2, which is normal for the streams in the Grande Cache area.

The Present Study

Field work carried out around orphaned open pit coal mines during the summers of 1977 and 1978 provided an opportunity to locate and sample leachates emanating from waste rock of a variety of lithologies. These materials had been weathering for twenty years or longer. The goal of this sampling and analysis was to determine if any major or minor trace elements or compounds were present in quantities that might prove to be a water pollution hazard. The sampling was not intended to be a year-round continuous monitoring program but rather a synoptic survey which "prospected" for possible sources of water pollution.

Chemistry of Leachates from Open Pit Mine Dumps

The descriptions of the open pit mine dumps and spoil areas where leachate samples and pond waters were collected are summarized in Table 3. Figures 2A-D present the results of analyses for major cations and anions.[1]

Field Methodology. At each sampling site, weather conditions, estimated flow rate, water temperature, and pH were routinely recorded. Samples were then collected for all or part of the following: physical chemistry (dissolved oxygen, specific conductance, alkalinity, turbidity, nonfilterable residue), total organic/inorganic carbon, extractable metals, dissolved metals, cyanide, nitrates, mercury, and organic compounds (hydrocarbons, organic sulphur compounds). Samples taken for dissolved metals analysis were filtered through a Satorius SM165-11 filtration apparatus containing a 0.45 micron membrane filter under a vacuum created by a Nalgene 6130 hand vacuum pump (Fig. 30.3). Prior to filtering each sample, the filtration apparatus was rinsed with 0.5 L distilled water. The rinse water was collected and bottled for analysis, and a fresh filter was placed within the apparatus. Following filtrations, the filter was removed and the apparatus rinsed with 1:1 NHO_3 solution and then given a second rinse with distilled water. One half litre of the dissolved metal sample was acidized with 1 ml concentrated HNO_3. Extractable metal samples were acidized in the same proportions without filtration. Samples obtained for mercury analysis were filtered and 0.25 L of the filtrate was placed in the Teflon bottle and preserved with 2 ml concentrated HNO_3 followed by 2 ml of 50% of $K_2Cr_2O_7$. Cyanide samples were filtered and 0.25 L of the filtrate was combined with 2 ml of a 50% NaOH solution. Water samples of 40 L each were obtained for analysis of organic compounds. The organic content of the water sample was extracted in the field by agitating hexane in the Squibb separatory funnel filled with sampled water.

All samples were packed in an insulated box and chilled during transport to the laboratory.

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[1] Compiled tables of data for leachate physical characteristics and concentrations of minor and toxic trace elements and organic compounds may be obtained from the author upon request.

TABLE 3

Description of Leachate Sampling Sites at Open Pit Coal Mine Dumps

Site No.	Site Name	Location (UTM)	Production Formation[1]	Dates Sampled (1978)	Parameters Sampled[2]	No. Years. of Dump Weathering	Description
X-1	McIntyre #9 mine dump	354500E 5989100N	L	7 Sept.	OC	0-4	Stream 0-2 of Hackbarth (1979). Stream fed by drainage from the #9 mine dump. Flow rate ~20 L/minute.
X-2	McIntyre #8 dump	360800E 5989400N	L	7 Sept.	OC	3-7	Spring at base of #8 mine. Sampled by Hackbarth (1979). Flow rate ~1 L/minute.
1	Mountain Park north pit seep	479250E 5864600N	L	14 June, 23 July, 8 Sept., 28 Oct.	PC, EM, DM, NFR, TOC TIC, Hg, HCN, N, DO	22	A series of seeps on the slopes of a shale and sandstone overburden dump. Flow rate ~1 to 0.5 L/minute.
3	Mountain Park plant dump spring	481850E 5863400N	L	as above	as above	22	Spring at base of a burning coal and coaly shale-rich waste dump. Spring decreased in flow rate from ~10 to ~0.5 L/minute during period of sampling.
4	Mannix south pit spring near Cadomin	480240E 5873850N	L	14 June, 22 July, 8 Sept., 28 Oct.	DO, PC, EM DM, NFR, TOC, TIC, Hg, HCN	26	Spring flowing from base of dump filling the original valley. Flow rate ranged from ~12 to ~4 L/minute during period of sampling.
5	Coal valley catch pond between north and south pits	513000E 5882150N	C	15 June, 22 July, 7 Sept., 27 Oct.	as above	20	Shallow catch pond draining both shale-rich and coal-rich waste dumps. Flow rate from ponds varied between 3 to 10 L/minute during sampling period.
6	Stream flowing into north pit pond, Coal valley	512000E 5883000N	C	15 June, 22 July	DO, PC, EM DM, NFR, TOC, TIC	20	Stream originating in muskeg and flowing through coal-rich spoil pile. Stream flow rate >15 L/minute.
6A	Spring at Sterco siding #47	511400E 5883400N	C	7 Sept., 27 Oct.	DO, PC, EM, DM, NFR, TOC, TIC, Hg, HCN, N	20	Spring at base of a mine dump containing coaly waste, clinkers, and iron debris. Flow rate decreased from ~2 to 1 L/minute during sampling period.
7	Nordegg stop pond	561950E 5812700N	L	15 June, 21 July	DO, PC, EM, DM, NFR, TOC, IC	22	Pond in coaly waste material fed by adit drainage.
8	Stream outflow at south pit	564650E 5809450N	L	15, 20 July	as above	22	Confluence of two small streams draining open pit mine. Flow rate ~1 to 2 L/minute.

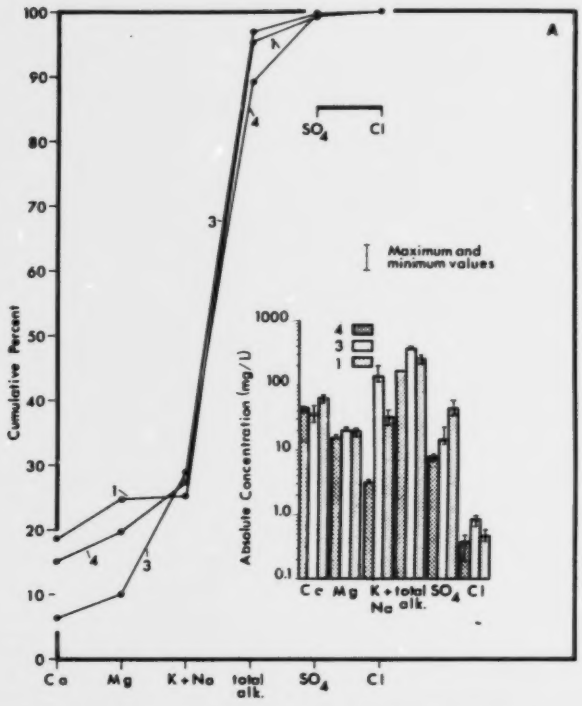
TABLE 3 (cont'd)

Site No.	Site Name	Location (UTM)	Production Formation[1]	Dates Sampled (1978)	Parameters Sampled[2]	No. Years. of Dump Weathering	Description
8A	Stream at toe of mine plant dump	562100E 5812900N	L	9 Sept., 27 Oct.	DO, PC, EM, DM, NFR, TOC, TIC Hg, HCN	22	Stream at toe of spoil piles containing coaly waste and ash debris. Flow rate >50 L/minute during sampling.
9	Grassy Mountain Mine, spring above Lake #4	685800E 5505050N	K	22 June, 25 July, 25 Aug., 29 Oct.	DO, DC, EM, DM, NFR, TOC, TIC, OC, Hg, NCN	16	Area of springs at the base of a spoil pile above Lake #4 at Grassy Mountain Mine. Flow rate decreased from 4 to 1 L/minute during sampling period.
10	Grassy Mountain Mine, pond below Lake #4	685700E 5504350N	K	22 June, 25 July	DO, PC, EM, DM, NFR, TOC, TIC	16	Pond occupying part of pit at Grassy Mountain Mine.
11	York Creek Mine, spring below north pit pond	680850E 5496950N	K	22 June, 25 July 25 Aug., 29 Oct.	DO, PC, EM, DM, NFR, TOC TIC, OC, Hg, HCN	22	Spring at base of spoil pile of sandstone and shale overburden waste. Flow rate ranged from >30 to <20 L/minute during sampling period.
12	Tent Mountain Mine, stream below overburden	665600E 5489150N	K	as above	as above	0-29	Stream sampled ~1 km below active dumps of Tent Mountain Mine. Flow rate ranged from >50 to 20 L/minute during sampling period.

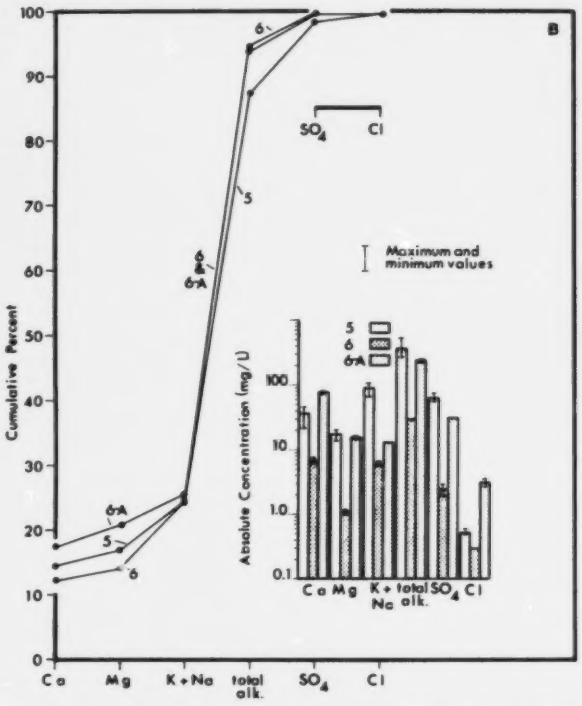
[1] L-Luscar, C-Coalspur, K-Kootenay

[2] OC - organic compounds
PC - physical chemistry
EM - extractable metals
DM - dissolved metals
NFR - nonfilterable residue
TOC - total organic carbon
TIC - inorganic carbon
Hg - mercury
HCN - cyanide
N - nitrogen oxide compounds
DO - dissolved oxygen

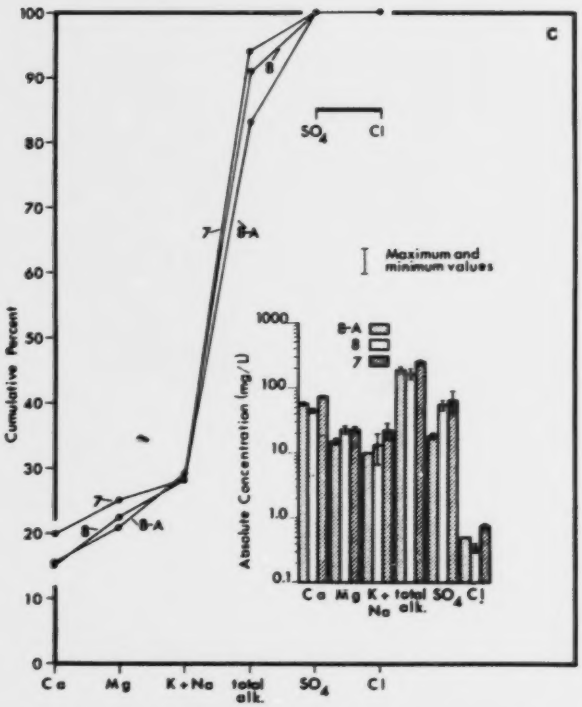
Figure 2. Major cation and anion chemistries in leachates from coal overburden waste dumps (for site descriptions cf. Table 3).



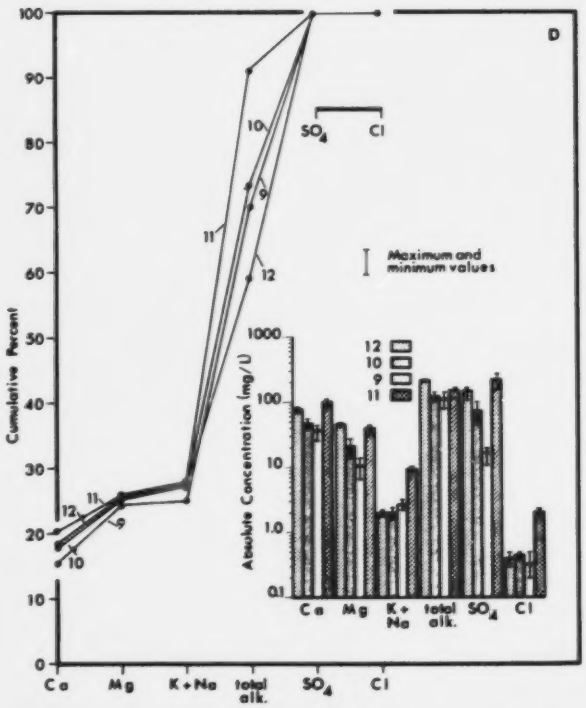
A - Luscar Formation overburden dumps and coal wastes in the Mountain Park-Cadomin area: 1 - Mountain Park north pit seep, 3 - Mountain Park plant dump spring, 4 - Mannix south pit spring near Cadomin.



B - "Coalspur Beds" overburden waste dumps, Coal valley: 5 - Coal valley catch pond between north and south pits, 6 - Stream flowing into north pit pond, Coal valley, 6A - Spring at Starco siding.



C - Luscar Formation overburden dumps and coal wastes in the Nordegg area: 7 - Nordegg strip pond, 8 - Stream outflow at south pit, 8A - Stream at toe of mine plant dump.



D - Kootenay Formation overburden dumps and coal wastes: 9 - Grassy Mountain Mine, spring above lake #4, 10 - Grassy Mountain Mine, pond below Lake #4, 11 - Spring below north pit pond York Creek Mine, 12 - Stream below overburden dump, Tent Mountain Mine.

Laboratory Methodology. Analysis of the samples, except those for analysis of organic compounds, was carried out by the Water Quality Branch of Inland Waters Directorate, Calgary, Alberta, following Environment Canada standard methodologies (Inland Waters Directorate, 1979). The samples for analysis for hydrocarbons and organic sulphur compounds were analyzed by Dr. S.A. Telang, of the Kananaskis Centre for Environmental Research of the University of Calgary, using gas chromatography.

Physical Characteristics. Samples were usually clear with generally small nonfilterable residues and low turbidities. The pH of leachates from the "Coalspur Beds" and the Luscar Formation wastes was generally less alkaline than that from Kootenay wastes. The few values that were slightly acidic were invariably associated with wastes that contained a large percentage of coal and coaly shales.

Dissolved oxygen levels were usually adequate to support fish, except for station 3 at Mountain Park which was responsible for the low mean and low minimum values for the Cadomin-Mountain Park area. The low dissolved oxygen values at this site are apparently the result of the dump burning. The significant dissolved oxygen contents of the leachates in most dumps indicate that the chemical weathering of the dumps is taking place under well oxygenated conditions.

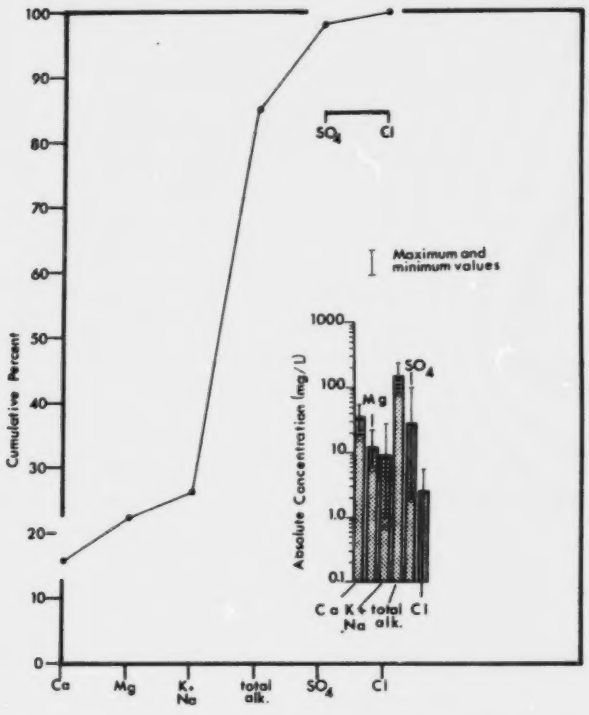
Water Chemistry of Undisturbed Coal-bearing Areas

Major Cations and Anions. The chemistries of streams in the Rocky Mountains reflect the presence of abundant carbonate minerals in the bedrock and glacial regolith. They are naturally alkaline with all pH values falling between 7.2 and 8.9. Total dissolved solids always fall well within acceptable drinking water standards. These concentrations range between 80 and 300 mg/L. Figure 3 shows cumulative per cent and absolute values for major cations and anions (concentrations $\geq$0.1 mg/L) from pristine basins. It can be seen from these figures that water chemistry is relatively uniform within the coal-bearing belts of the Rockies. The alkalinity of the surface waters is almost entirely due to bicarbonate ion which is the dominant anion (carbonate concentration is almost zero over this pH range). Sulphate concentration varies greatly with values from less than 1.0 to 100 mg/L, as does chloride concentration from less than 1.0 to 10 mg/L. Calcium and magnesium are the dominant cations. The sum of the concentrations of calcium and magnesium expressed as equivalents is approximately equal to the concentrations of bicarbonate expressed as equivalents. Potassium concentration is usually less than 1 mg/L whereas sodium concentration ranges from less than 1 to 10 mg/L. Sodium concentration is usually greater in streams draining terrain underlain by the Luscar Formation and the "Coalspur Beds" than for terrain underlain by the Kootenay Formation.

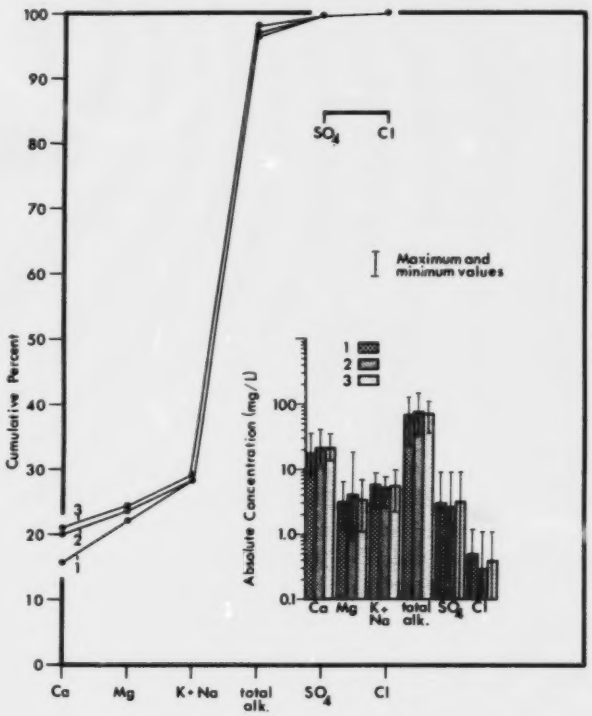
Sulphate concentrations are independent of calcium concentrations; therefore the sulphate does not originate from gypsum in the bedrock but rather from the oxidation of sulphide minerals or sulphur-containing organic compounds present in shales.

Total dissolved solids (TDS) and major cations and anions follow general seasonal cycles in concentration. TDS and major ion concentrations are usually lowest in the spring and early summer when snowmelt and precipitation are at their maximum and greatest in fall and winter when groundwater seepage becomes the most significant source of water supplying streams. TDS range from values as low as 60 to almost 300 mg/L. Silica is present in quantities ranging from less than 1 to about 16 mg/L.

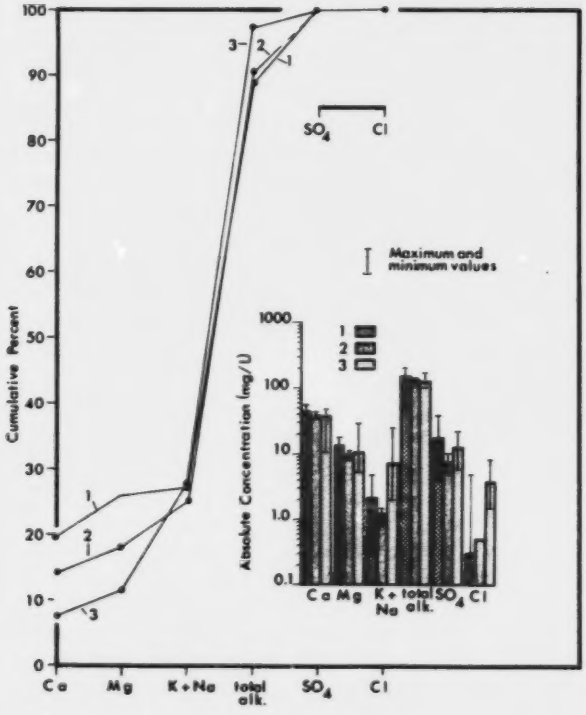
Figure 3. Major cation and anion chemistries for pristine streams in coal producing areas.



A – Streams flowing over terrain underlain by the Luscar Formation in the Grande Cache area (from Hackbarth, 1979).



B – Tri Creek basin (predominantly underlain by the Brazeau Formation which is composed of sediments similar to the "Coalspur Beds"): 1 – Wampus Creek, 2 – Eunice Creek, 3 – Deerlick Creek.



C – Streams flowing over terrain underlain by the Kootenay Formation and stratigraphically adjacent rocks: 1 – Middle Fork Creek, Marmot Creek experimental watershed, 2 – Cabin and Howell creeks, 3 – upper Elk river.

Dissolved oxygen levels are usually in the 10 to 12 mg/L range, typical of well oxygenated mountain streams. Exceptions exist locally where bogs feed oxygen-poor water to streams.

Minor and Toxic Trace Elements. Although numerous gaps exist in the available data, concentrations of toxic or problem trace elements or compounds[1] are within Environment Canada drinking water standards (McNeely et al., 1979) for pristine streams in coal-bearing areas.[2] Occasionally, however, high values do exceed these limits. The high values shown in Table 4 were confined entirely to the winter months when stream waters are largely sustained by groundwater seepage.

Dissolved trace elements, which are likely to be present in surface waters in detectable or excessive concentrations during low flow periods due to groundwater discharge, can possibly be predicted in some of the areas studied by analysis of groundwater chemistries. For example, high values of cadmium, lead, mercury, and total phosphorous were found in groundwaters sampled from exploratory wells drilled for the proposed Elco Mine in upper Elk Valley, British Columbia (Elco Mining Ltd., 1978, unpublished report). High concentrations of cadmium and mercury were recorded during winter sampling of streams in this area (Table 4).

Organic Compounds. Naturally occurring organic compounds and constituents that are commonly analyzed for in stream waters of the Rocky Mountains and Foothills include total organic carbon (TOC), phenols, ammonia, and oxides of nitrogen.

Organic compounds in the stream waters of the Marmot Creek experimental watershed were studied in detail by researchers of the Kananaskis Centre for Environmental Research at the University of Calgary. The absolute concentrations of TOC averaged 4 mg/L during the five year study period. Only about 25 per cent of the organic compounds present could be identified. About 80 per cent of the identified compounds were humic and fulvic acids. The balance of the identified compounds consisted of tannins, lignins, carbohydrates, hydrocarbons, phenols, fatty acids, and amino acids. None of these compounds occurred in concentrations which exceed acceptable limits for drinking water where limits for these compounds have been established. However, the maximum acceptable concentration of phenolic compounds for the protection of freshwater aquatic life of 0.001 mg/L was exceeded naturally by concentrations of phenols up to 0.090 mg/L. It appears likely on the basis of the Marmot Basin data that phenol concentrations probably exceed guideline concentrations elsewhere within similar coal-bearing areas in the Rocky Mountain Foothills and Front Ranges.

The organic substances found in pristine stream waters are almost entirely derived from soil leachates or biological processes within the stream themselves (B.L. Baker, personal communication, 1979). Nitrogen oxides are all of low concentration and well within drinking water standards of 10 mg/L. Data on ammonia are available only for the Marmot Creek basin and the upper Elk River basin; concentrations are within the 0.5 mg/L acceptable limit in Marmot basin but are greatly exceeded in the Elk basin. The presence of extensive bogs in Elk valley may provide the ammonia through seepage of anaerobic waters during the winter months when the high ammonia values are recorded. More work on this phenomenon would be required, however, for a definite explanation.

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[1] These include: dissolved and extractable iron, manganese, arsenic, copper, chromium, nickel, lead, zinc; dissolved fluoride, aluminum, cadmium, boron, selenium; extractable mercury and vanadium; and total inorganic phosphate and total phosphate.

[2] A tabular data summary is available for the author upon request.

TABLE 4

Elements and compounds exceeding permissible concentrations in streams largely or entirely originating from undisturbed coal-bearing drainage basins in the Rocky Mountain Foothills and Front Ranges of Alberta and British Columbia

Parameter	Location	Maximum Value	Range of means from available basins	No. Samples	Environment Canada maximum permissible concentration for	
					drinking water	protection of freshwater aquatic life
Dissolved Manganese	Marmot Creek experimental watershed	2.60 mg/L	≤0.01-0.013 mg/L	704	0.05 mg/L	not determined
Dissolved Fluoride	as above	1.6 mg/L	0.07-0.17 mg/L	910	≤1.5 mg/L	as above
Dissolved Cadmium	Upper Elk River Valley	0.050 mg/L	≤0.005 mg/L	32	≤0.005 mg/L	≤0.002 mg/L
Dissolved Lead	Marmot Creek experimental watershed	0.034 mg/L	≤0.001-0.002 mg/L	302	≤0.05 mg/L	≤0.03 mg/L
Extractable Mercury	Smoky River above Hills Creek (Grande Cache area)	0.13 µg/L	not detected to 0.07 µg/L	49	≤1.0 µg/L	≤0.1 µg/L
	Upper Elk River valley	0.8 µg/L	not determined	43		
Total Phosphates	Marmot Creek experimental watershed	0.228 mg/L	≤0.005-0.022 µg/L	551	≤0.100 mg/L	≤0.025 mg/L

Water Chemistry of Leachates from Orphaned Open Pit Mines

Major Cations and Anions. The range of variations of mean, maximum, and minimum concentrations of major cations and anions was found to be generally similar from one coal producing formation to the next (Fig. 2). Individual values, however, range widely from site to site. Only two apparent systematic variations between leachates on a formation to formation basis were found. A higher relative per cent concentration of sodium was found in leachates from the "Coalspur Beds" and Luscar Formation relative to the Kootenay Formation leachates. Conversely, a higher relative content of sulphate was found in Kootenay leachates relative to the contents of Luscar and "Coalspur Beds" leachates (Fig. 2). The relatively higher contents of sodium in the Luscar Formation and the "Coalspur Beds" are undoubtedly due to the presence of sodic shales in these units and their absence from the Kootenay Formation (Table 1A). The higher sulphate content, apparently at the relative expense of alkalinity, is probably the result of more rapid oxidation and/or higher concentrations of sulphur compounds in the Kootenay Formation than in the other two. This relationship would be expected where iron sulphide minerals are present. This high sulphate content relative to alkalinity persisted in both station 12 samples (Table 3), which were obtained below the still active Tent Mountain Mine dump, and the Grassy Mountain Mine site (stations 9, 10) which has been inactive for approximately 20 years. By contrast, leachates from the York Creek dump (site 11), which consists mostly of coal and coaly shale fragments, contain the lowest relative sulphate content.

All values for the concentrations of major cations and anions measured in waste dump effluents and ponds are accetable for drinking water (McNeely et al., 1979).

Minor and Toxic Trace Elements. Thirteen minor and toxic trace elements were sampled in the mine dump leachates.[1] Of these, only dissolved iron and manganese exceeded Environment Canada permissible guidelines (McNeely et al., 1979) for drinking water ($\leq$0.3 mg/L and $\leq$0.05 mg/L, respectively) and the protection of aquatic life ($\leq$0.3 mg/L) for iron only. No levels have yet been set for manganese by Environment Canada. In only one case, copper exceeded Environment Canada guidelines for the protection of aquatic life ($\leq$0.005 mg/L). With respect to the elevated iron and manganese values, it can be noted that the permissible standards are frequently exceeded in natural surface waters within coal-bearing areas of the Rocky Mountain Foothills and Front Ranges (Table 4). The elevated level of copper is anomalous and requires further investigation. This value was associated with the Kootenay Formation and may be the result of local leaching of shales by sulphuric acid generated by the weathering of pyrites.

The general absence of excessive levels of toxic trace elements in the leachates probably reflects chemical conditions in the dump sediments which cause minerals containing these elements to remain almost insoluble. If toxic trace elements are released they must be quickly immobilized.

Organic Compounds. Total organic carbon, total nitrogen, cyanide, total inorganic and total organic phosphate contents were determined for dump leachates. In addition five samples were collected for analysis of organic sulphur compounds and hydrocarbon compounds. Phenols were inadvertently omitted during field sampling. Ammonia was not sampled since blasting had long since ceased at all sites except Tent Mountain. All values were well within drinking water standards. The values for total

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[1] These include: dissolved and extractable iron, manganese, aluminum, arsenic, cadmium, chromium, copper, lead, vanadium; dissolved boron, fluoride, selenium; extractable nickel and mercury.

nitrogen and total inorganic phosphorus and total phosphorus included one sample from each established station plus some synoptic sampling from flooded pits nearby. The phosphorus present in the waters was found to be of inorganic origin. The additional five samples of leachates were obtained from stations X-1 and X-2 near Grande Cache, station 3 at Mountain Park, and stations 9 and 11 in the Crowsnest Pass area. Detection limits for these hydrocarbons and organic sulphur deposits using gas chromatography is approximately 10 ng/L (10^{-9} g/L). None of these substances were detected. Collection sites ranged from active dumps to burning coaly waste piles which have been abandoned for almost 30 years.

Discussions and Conclusions

Although it is tempting to make a comparison between the chemistries of pristine waters and leachates based upon the data reported in this paper alone, none will be made. The synoptic nature of the sampling and the limited size of the leachate data base prohibits such a comparison. The ranges of concentrations of major cations and anions in the leachates, however, fall into the same range as those reported by Hackbarth (1979) after seven years of spoil weathering in the Grande Cache area. This may indicate that leachate chemistry shows a progressive increase in major cation and anion concentrations for the first decade and then levels out with concentrations of each parameter at two to four times the values found in pristine streams. Further monitoring will be required to confirm this.

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Mining Influences on Groundwater Flow and Chemistry
Lionel Jackson, Geological Survey of Canada

P. ZIEMKIEWICZ

I was interested in your comment regarding ammonia coming out of bogs. We often hear two arguments:

1) Elevated N-levels (nitrate, ammonia) are common in surface water after mining.
2) The N originates from either ANFO blasting powder or as a natural product of the oxidation of the ammonium on shales. Have you any idea where this nitrate is coming from and how persistent the elevated levels are?

L. JACKSON

We looked at nitrogen here too - it was very low, something like 1 milligram/litre. I think we would have picked it up had there been elevated quantities of ammonia present. I think it is probably due to the explosives and it is a transitory type of phenomenon.

R. FERSTER

You have been looking at weathering of materials. Do you have anything on that yet?

L. JACKSON

How rapidly they breakdown?

R. FERSTER

Yes.

L. JACKSON

What we have observed is a drying zone near the surface where basically, all the breakdown takes place. Below that, there is basically no breakdown. This is dismal for reclamation purposes, as the material underneath is virtually like rock. What we did find is that areas where soil and regolith are stockpiled and this material is re-spread, you have roots going down up to two feet.

L. JACKSON

My concern is with nitrates at peak periods. I think the biggest problem is from the public health standpoint. That nitrate may go into someone's drinking water.

P. ZIEMKIEWICZ

And phosphates?

L. JACKSON

The evidence I've seen from the Rockies is you get higher phosphate levels coming from the groundwater than from mine spoils.

B. COSTERTON

At Luscar it appeared the sulphur phenomenon was overriding the septic concern.

R. FERSTER

I have only one comment to make. We have people here from government and from industry. We have identified problems, but I feel we have to look at the regulatory aspect as well. From a mining standpoint, it takes three months to get an impoundment approach and everyone recognizes problems, but no one has the answers. The companies are trying to do their best, but guidance is not being provided. The economics involved in particular situations have also to be considered by regulatory agencies. I hope the participants take these points into consideration when completing the questionaire.

MINING EFFECTS

ON

SURFACE HYDROLOGY

by

Franklin D. Davies, P. Ag.
Hydrology Branch
Technical Service Division
Alberta Environment

for

Alberta Energy and Natural Resources
Workshop on the Effects of Mining on
East Slopes Hydrology

MINING EFFECTS ON SURFACE HYDROLOGY

BY: Franklin D. Davies
Alberta Environment

ABSTRACT

The mining process virtually changes every parameter in the local hydrologic cycle from it's natural state. Physical changes due to mining may cause the natural pre-hydrologic condition to change several fold. Using a 1 to 10 year storm event as design criteria may by very short sighted considering the range of changes in the hydrologic cycle that can be impacted on the environment by the mining process. Dividing the hydrologic cycle into the cycle components permits an evaluation of the effect of mining on the processes themselves. This enables an evaluation of mining design on the hydrologic cycle as opposed to considering the hydrologic effect on mining.

1. INTRODUCTION

There is a considerable difference in viewpoint between the mining effects on surface hydrology and the effects of surface hydrology on mining. The difference is that you are looking at things from an opposite direction. We have therefore attempted to look at them from the view of mining effects on the hydrologic cycle not surface hydrology on mining. This approach may have some merit in solving the miner's problems on environmental disturbances. With this in mind we approach the subject.

2. HYDROLOGIC PROCESS AND THE FACTORS THAT AFFECT THE PROCESS

The first aspect of identifying what affects mining may have on the hydrologic cycle is to identify the various processes within that cycle that mining operation could affect. So to get a general view and a reminder of the process lets look at the overall hydrologic cycle. Figure 1 is a diagram of the hydrologic cycle.

Picture of the hydrological cycle

- Atmospheric and evaporative processes gather up water into the "airways" from its oceanic supplier.
- Gently or not so gently it is delivered by "heavens transport systems" to its users.
- Natures ground folks (trees, shrubs, grass, soils, etc.) reach out to soak or gather up their needs.
- Storage containers of all kinds are used to collect it (lakes, potholes, sloughs, soils, etc.)
- excess supplies are collected to be returned back to the source from where it came from.

And if you are not inclined to look at the pictorial or poetic view another way to describe it is to break it down diagramically as in Figure 2. Here we have compartmentalized the processes showing the flow links through which it travels.

THE HYDROLOGICAL CYCLE

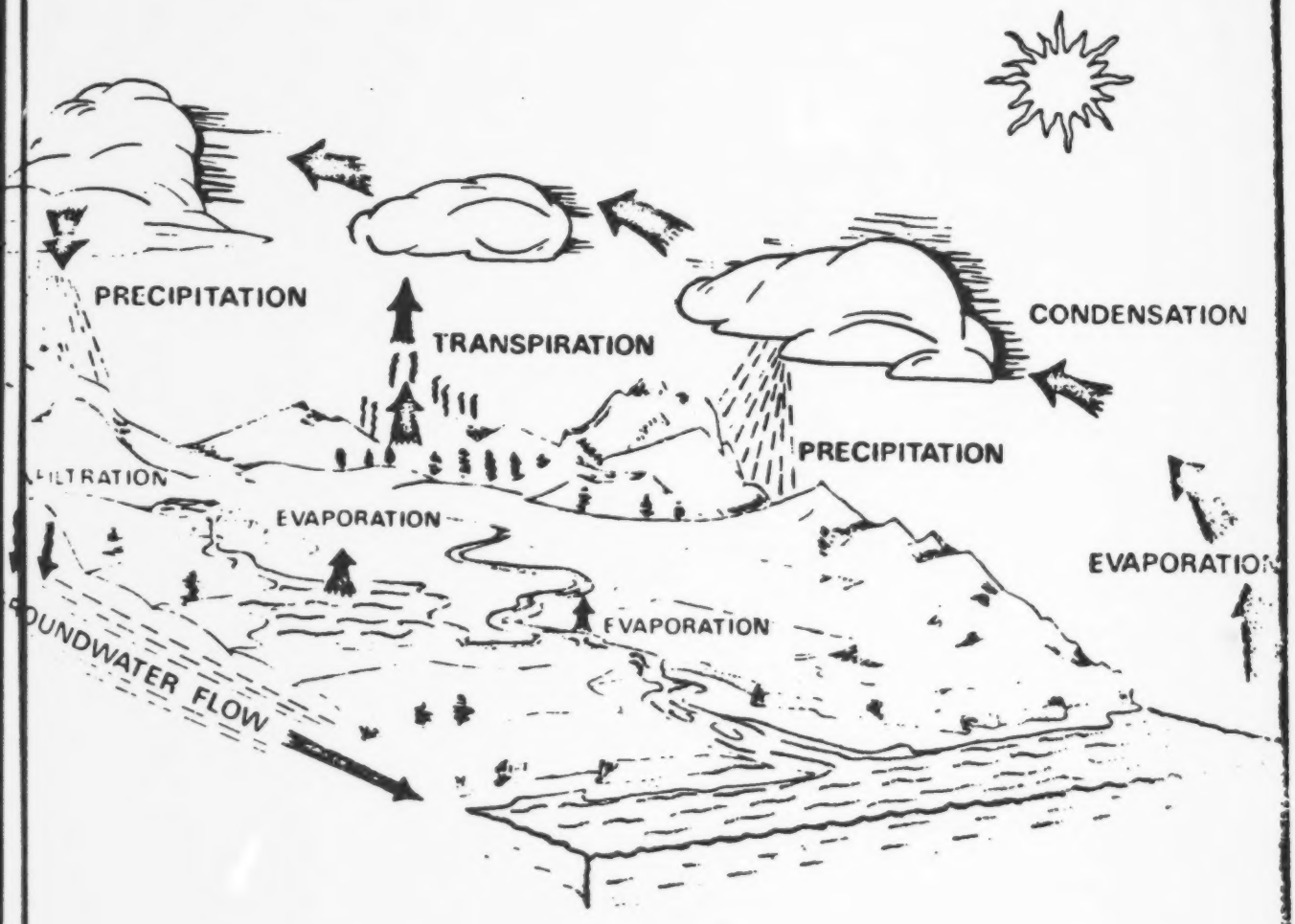


Figure 1

Storage Compartments and Flow Links in the Hydrologic Cycle

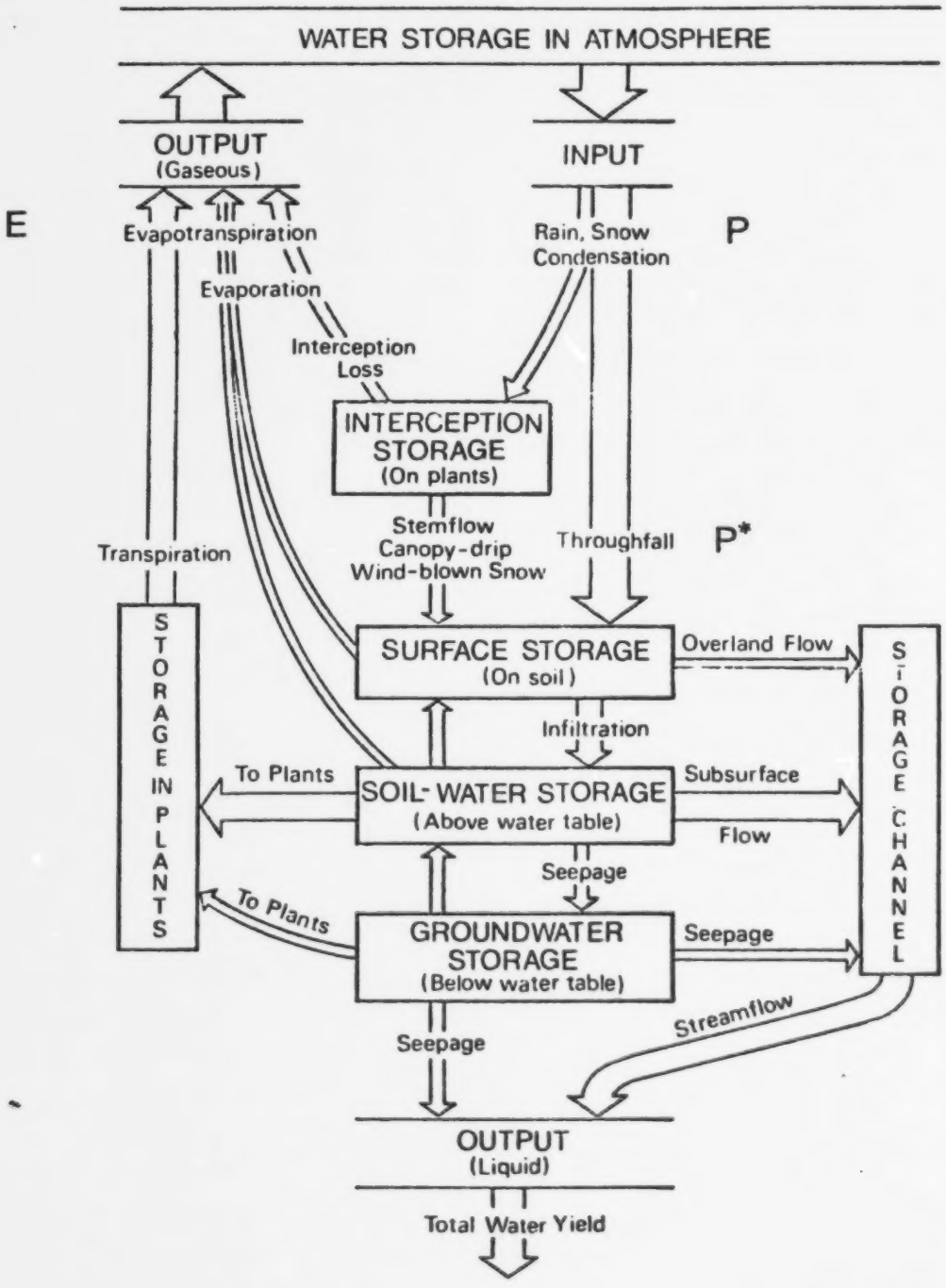


Figure 2

From An Approach to Water Resources Evaluation of Non-Point Silvicultural Sources. U.S. Forest Services Washington DC Pg III 3

TABLE 1

HYDROLOGIC PROCESSES AND THE FACTORS AFFECTING

CHANGES IN THE HYDROLOGIC PROCESSES

Controlling Processes	Factors Affecting the Processes
The Availability of the Water Supply	
Rainfall	Temporal and areal variability
Snowmelt	Antecedent Areal variability of snowpack Snowpack temperature Snowpack density Snowpack air and water content and heat transfer and storage properties Formation of ice planes Cover, exposure Soil temperature Melt period Solar radiation Air temperature Wind velocity Rainfall Long-wave radiation Dew point temperature
Release of Excess Water	
Infiltration	Antecedent Soil type Soil condition Soil moisture content Extend to which soil is frozen Cover Ground-water level Water-excess period Water-availability rate
Evapotranspiration	Cover condition and type Solar radiation Wind velocity Air temperature Water temperature Humidity Soil moisture content Soil type

Table 1 Continued

Table 1 concluded

Controlling Processes	Factors Affecting the Processes
Release of Excess Water (cont'd)	
Pocket storage	Soil type Terrain
Interception	Cover density and type Till practices Season of year
The Routing Process	
Overland flow	Basin slope Cover
Depressional storages	Percentage of storage already filled Contributing drainage area Ground-water level
Ground-water flow	Hydraulic connection of moisture excess/ground water/drainage channels
Interflow	Hydraulic connection of moisture excess/interflow conduits/ drainage channels
Channel flow	Antecedent Channel-storage level Channel-cover condition Runoff period Channel slope Channel geometry Backwater conditions
Overbank storages	Stream valley shape Channel capacity Backwater conditions
Reservoir storages	Percentage of storage already filled Contributing drainage area

- Rain and Snow are input processes
- Vegetative interception losses take place
- soil contact begins
- release and redistribution processes take place
  - Evaporation
  - Transpiration
  - Sublimation
  - Surface flow, (storages)
  - Inter flow (storages)
  - Groundwater flow

A third way to describe the process is to tabulate the processes and list all the factors affecting the process as in Table 1.The questions we asked was, are there any parameters in Table 1 not affected? If a change is made, all parameters are changed at some time or place.

3. THE EXPOSURE - DISTURBANCE PROCESS OF THE MINING OPERATION

What I am supposed to address today is the influences of mining on the hydrologic cycle just described. To do that we thought we had best look at it at the "process level" (compartment level) and see just how mining could be affecting the hydrologic process (locally or regionally)

In the east slopes we are likely to be mining under forested conditions. This may mean removal of all vegetation from a given area. What is the impact of deleting transpiration in the cycle on the other cycle components by removing the forest cover? At this point lets just consider the go lightly policy where the ground itself is not disturbed. Trees are carefully removed but the ground itself is not exposed. This means we have modified the evaporation and evapotranspiration (compartment) processes.

The results of small watershed studies all over the world are now reporting the extents that forest harvesting can change the volume of runoff. "In general forest clearing has resulted in an increased water yield, approximately 25% more" (Pg. 2 - Forest Management to Increase Water Yield A. Literature Review by R. Swanson)
The following is a summary of a few case studies.

3.1 Wagon Wheel Gap Watershed Study, Colorado

Results: Average annual water yield increased 25 mm or 15% for the seven years of study following logging (Bohes & Henry 1928).

3.2 Fool Creek Colorado (Goodell, 1958, Alexander & Watkins 1977)

Results: Annual streamflow has increased by an average 74 mm or 24% of observed runoff of 300 mm for the years (1956-1978) (Troendle & Leaf 1981).

3.3 Marmot - Kananaskis Valley Alberta

Preliminary unpublished results used "the four complete data years 1976, 1977, 1980, 1981 water yield from Cabin Creek has averaged 365 mm which is 50 mm more than the 315 predicted from the untreated control catchment (Middle Creek)".

The maximum potential for increasing water yield due to forest removal is, the extent of actual evapotranspiration occurring from the forest. In practice these increases will fall short of the total potential.

The above example indicates what mining influences may have on the evaporation section of the hydrologic cycle, by simply removing the evaporation component in the cycle. This change must now be handled by and through the soil and channel section of the cycle.

4. THE EFFECTS OF LAND DISTURBANCES

Let's now move over into the soil's storage compartments of hydrologic cycle. The soils themselves have a wide range of properties that resist, and or are affected by the changing input sequences of the Hydrological cycle. All you have to do is look at the classic profiles of Canadian Soil Orders (Fig. 2A), to recognize the extent of wide range in soil properties.

If you can visualize the systematic exposure of those soil horizons to a given water input you will recognize the great variety of water runoff response you might get.

When you think of mining, soil disturbance and construction you likely equate that in terms of soil erosion. Soil disturbance does affect the properties and capacities of soils to store, release, absorb, water from/through, over itself.

Here's a quote from a sediment yield study on Construction sites.

> "Soil loss on construction sites is about 10 times that on land in raw crops, 200 times greater than on land in pasture and 2,000 times greater than that on forested lands." (Dillaha 1982)

I thought that statement was a bit harsh on the effects of soil disturbances so I went and looked up the stream sediment yield of Spring Creek watershed.

Spring Creek is a watershed study started back in 1966 by Alberta Environment. Sediment sampling started in the basin in 1967. In 1977 the construction of a pipeline cut across the lower section of the study basin. Heavy sediment losses were noticed and an intensive sediment yield study of the whole basin was undertaken. Results of the study showed that 2.4% of the total area was producing 90.5% of the mean annual sediment losses. They further showed that the sediment yield from the pipeline right of way crossing the bed of the streams was 825 times greater than the watershed just upstream of the right of way which happens to be in the 2.4% high sediment yielding zone of the basin.

4.1 How the Disturbance Process Affects the Soil's Properties and Thus Change Their Affect on the Hydrologic Cycle

What causes this impact on the soil properties is basically a physical response to the changing interplay of variables in soil properties, climatic, hydrologic, and sometimes man's activities.

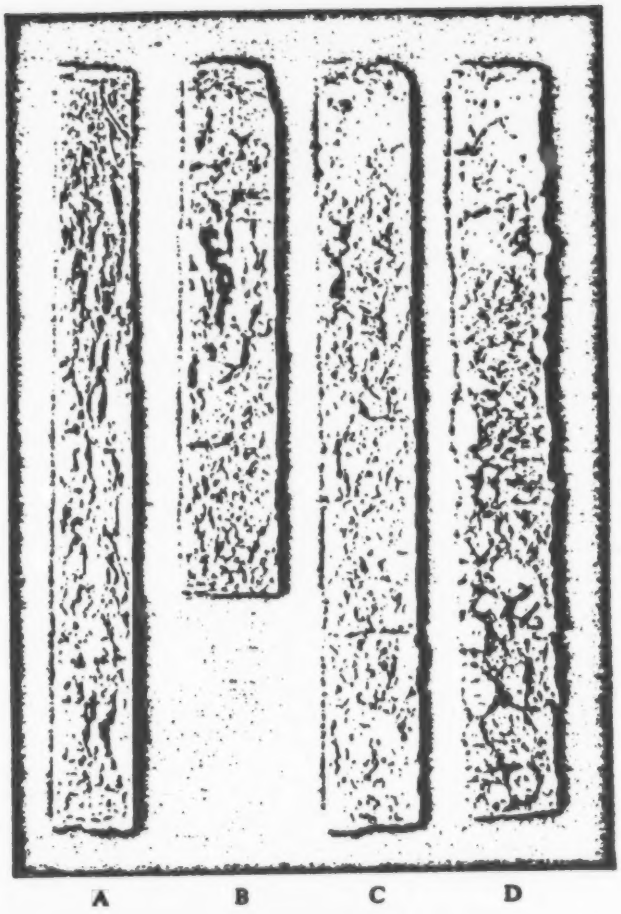


Fig. 1. Soil monoliths representative of the (a) Chernozemic, (b) Solonetzic, (c) Luvisolic, and (d) Podzolic soil orders.

From: Agriculture Canada
"The Systems of Soil Classification for Canada"

Figure 2A

Let's consider the single factor of Water permeability to the soil. This factor has a great deal of influence on the discharge rate and quantity of runoff. To get a visual concept in mind let's look at a mining complex and their surroundings - PICTURE (Not available for publication).
Note the difference in exposure and disturbance.

Figure 7 is an overlay of a typical road crossing leading over a small stream into the Alberta Eastern Slopes (Marty 1978). Figures 3 to 6 are samples of storms all along the East slope watersheds from the U.S. border to the Peace River Country. Note that these single storm inputs range from 75-300 mm of water depth. Table 2 is a sample of some recorded one day runoff depths from natural basins in Alberta. The runoff depth from these basins range from 25-125 mm in one day. Let's apply a sample from one of these storms on the road above.

What do you think the permeability change of the roadway from pre to post road construction would be?

What do you guess the runoff coefficient may change from? Well let's give it a pre runoff coefficient of say 30%. Post runoff coefficient of say 95%, we have to wet the road some. We now take one of the storms and calculated the increase runoff pressure that the soils at the roadside must take due to road construction.

Let's have a 150mm rainstorm
natural runoff coefficient .30 = 45 mm runoff
Road runoff coefficient .95 = 143 mm runoff
thats a unit area runoff increase of 316%

Now channel that 316% increased (3.16 times larger) unit runoff value over the entire surface of the road. Let's say the unit runoff due to road construction creates a 3 fold increase in surface area. It is channelled down a 45 degree incline to the bottom of the barrow pit. That's a 25 degree greater incline than normal. The physical change due to road construction have produced a 9 fold increase in runoff pressure on the soil characteristics at the side of the road. That doesn't include any variation for changes in storm intensity or the change in impact on the newly created channel in the bottom of the barrow bit to the stream.

5. PROCEDURES FOR EVALUATION OF THE HYDROLOGIC PROCESS THAT MINING COULD BE AFFECTING

Over the last 5 to 10 years each of the hydrologic compartments described in Figure 2 have had that particular process modelled by someone. The following is a list of some of the component models available.

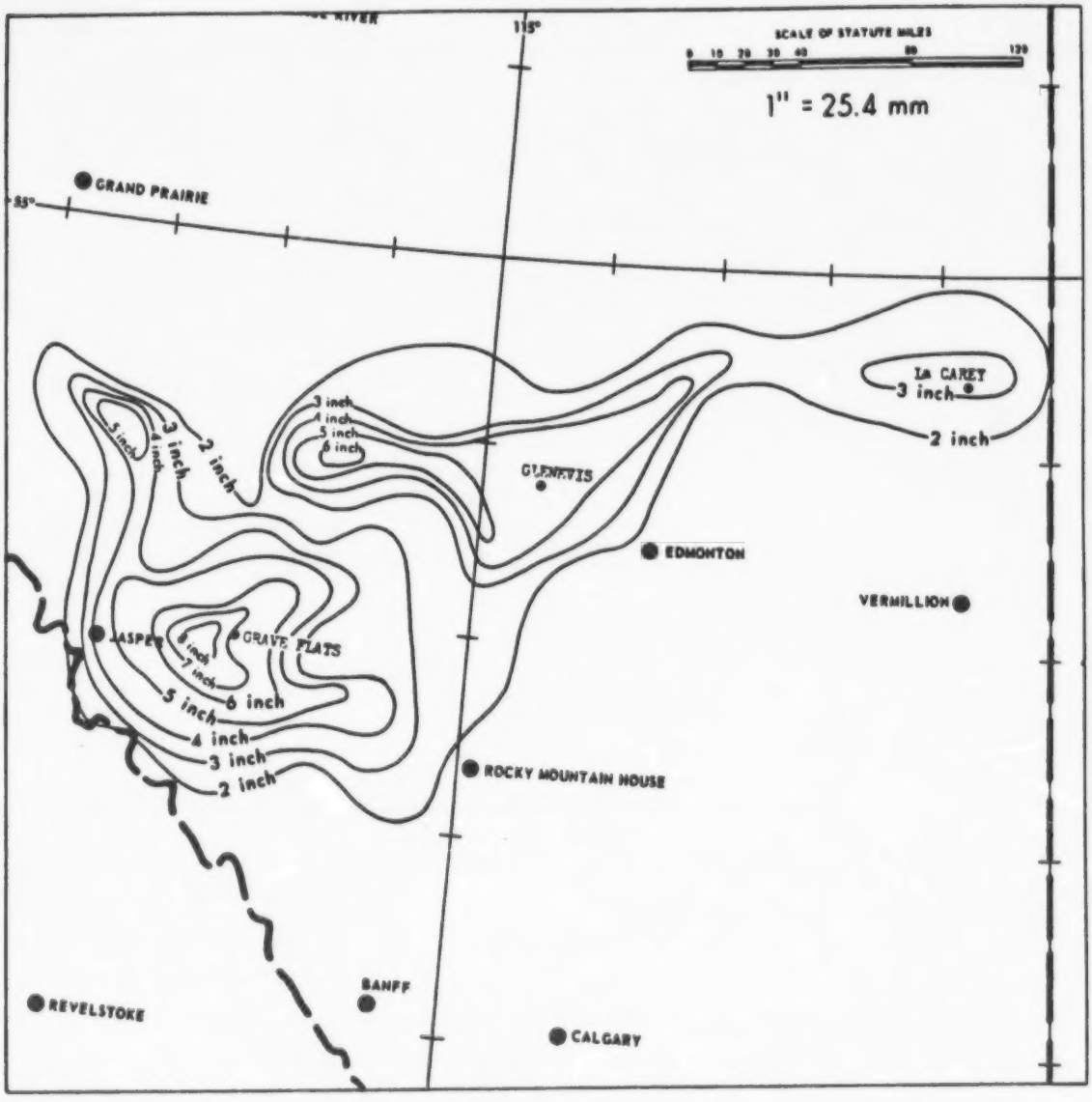
Process	Possible evaluation
Precipitation	Rainfall intensity analysis (1978 AES publication)
Evapotranspiration changes	Morton's Areal Evap. (Morton 1982)
Tree Removal	WRENS - U.S. Forest Service (1980)

TABLE 2
A SAMPLE OF ONE DAY RECORDED RUNOFF DEPTH FROM SMALL WATERSHEDS
IN THE PROVINCE OF ALBERTA

		Drainage Area K^2	Instantaneous Peak Discharge CMS/k^2	Mean Daily Discharge CMS/k^2	dam^3/k^2 = mm depth	Years of Recorded Data
1	Waterton River at International Boundary	160	2.1938	1.2875	111.2	17
2	Belly River at Mountain View	319	1.4543	1.0376	89.65	63
3	Drywood Creek near Turn Butt	29.3	1.3600	0.9522	82.27	46
4	Castle River at Ranger Station	376	1.0691	0.7899	68.25	14
5	Fish Creek near Priddis	259	0.7722	0.7683	66.38	33
6	Pincher Creek at Pincher Creek	155	1.11	0.5316	45.93	39
7	Pekisko Creek at Pekisko	203	-	0.4882	42.18	31
8	Lee Creek at Cardston	308	1.0497	0.4903	42.36	65
9	Sheep River at Buck Ranch	453	0.6689	0.4128	35.66	19
10	Swan River near Swan Hills	156	0.5410	0.3577	30.91	11
11	Wampus Creek near Hinton	25.4	0.8031	0.3146	27.18	15
12	Twin Creek near Seebe	2.64	0.3455	0.3093	26.72	17
13	Cardinal River at the Mouth	484	0.4897	0.3079	26.6	19
14	Saddle River near Woking	539	0.8145	0.2783	24.051	14
15	Bridlebit Creek near Valleyview	19.7	-	0.2614	22.58	14
16	Ram River at Ram Glacier	3.63	0.6860	0.2466	21.30	7
17	Wolverine Creek near Valleyview	9.84	-	0.2390	20.72	14

ISOHYETAL CHART

CODE NO:
ALTA-8-69



RAIN GAUGE DENSITY (SQ. MI./GAUGE) FOR STATED ISOHYET 8"-0, 7"-0, 6"-640, 5"-670, 4"-460, 3"-390, 2"-250

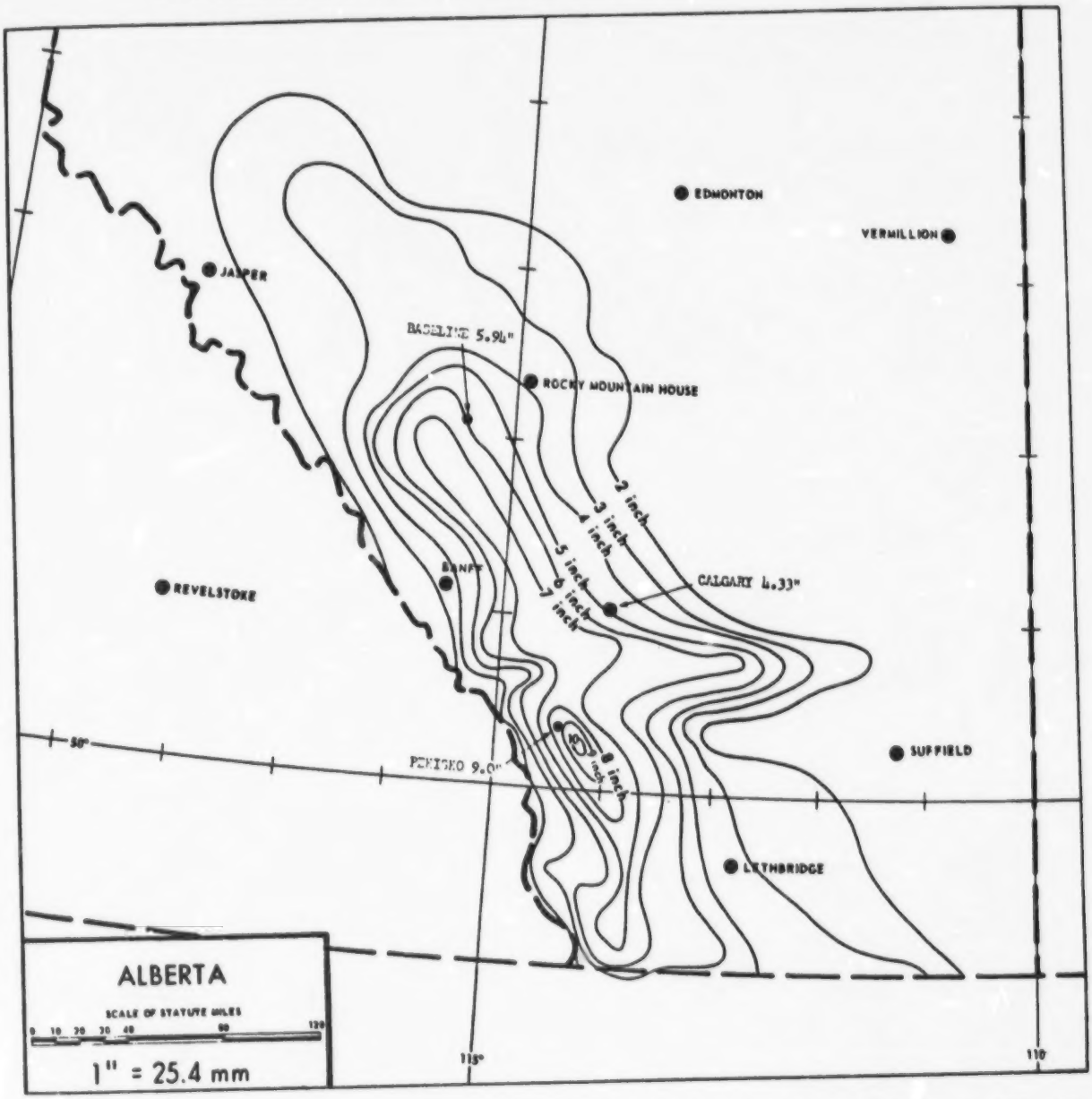
NUMBER OF RECORDING RAIN GAUGES: Four

SCALE OF ISOHYETAL WORK CHART: 1"- 40 Statute Miles

FIGURE 3

ISOHYETAL CHART

CODE NO:
ALTA-6-69



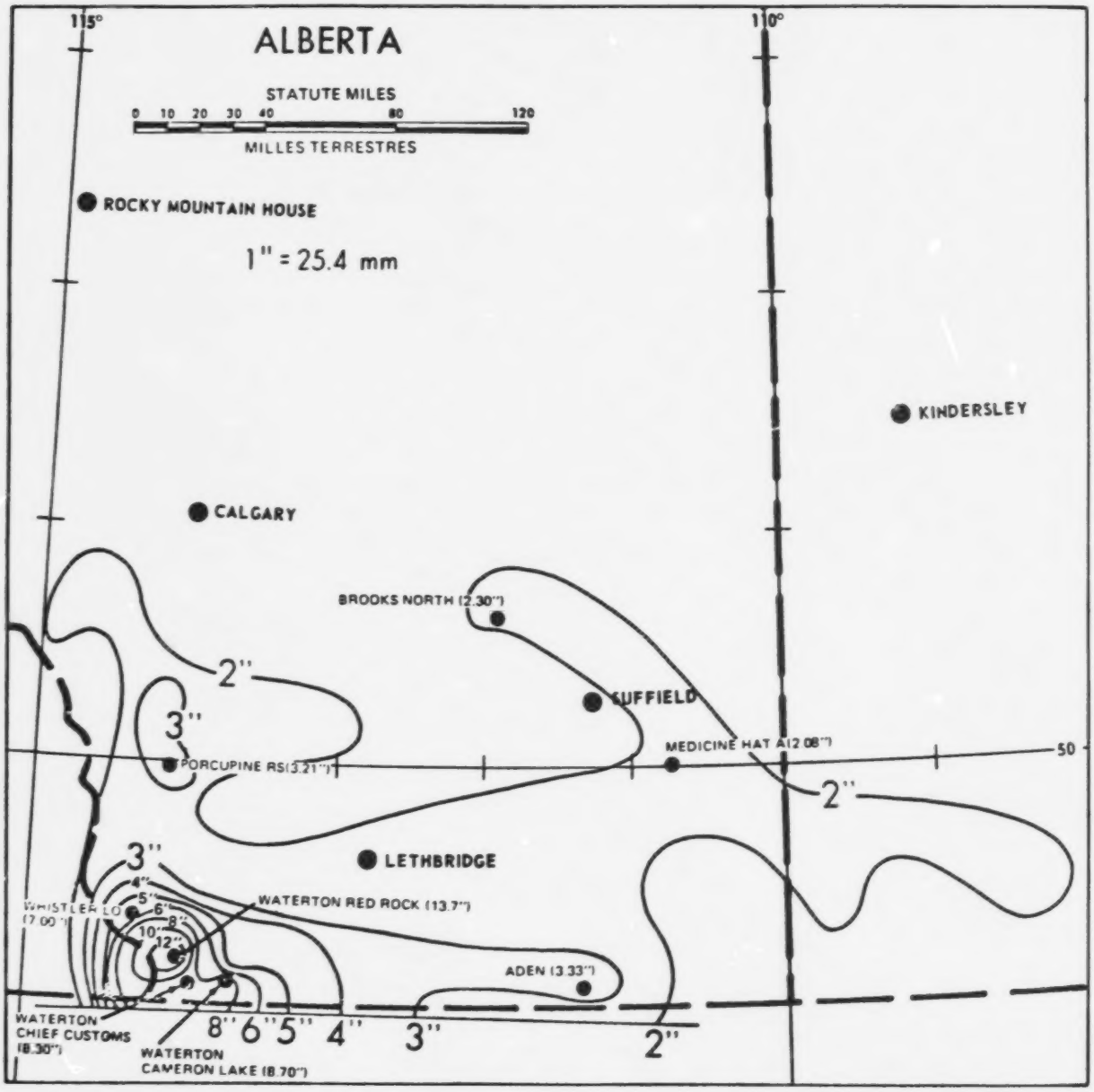
RAIN GAUGE DENSITY (SQ. MI./GAUGE) FOR STATED ISOHYET 10"-0, 9"-0, 8"-450, 7"-520, 6"-310, 5"-190, 4"-150, 3"-200, 2"-20

NUMBER OF RECORDING RAIN GAUGES: Six
SCALE OF ISOHYETAL WORK CHART: 1":40 Statute Miles

FIGURE 4

ISOHYETAL CHART
CARTE D'ISOHYÈTES

CODE NO:
CODE Nº: ALTA–6-75



RAIN GAUGE DENSITY (SQ. MI./GAUGE) FOR STATED ISOHYET
DENSITÉ DU RÉSEAU DE STATIONS PLUVIOMÉTRIQUES (MILLES CARRÉS/PLUVIOMÈTRE) POUR L'ISOHYÈTE DONNEE
12" = 213 8" = 167 6" = 221 5" = 174 4" = 185 3" = 212 2" = 386

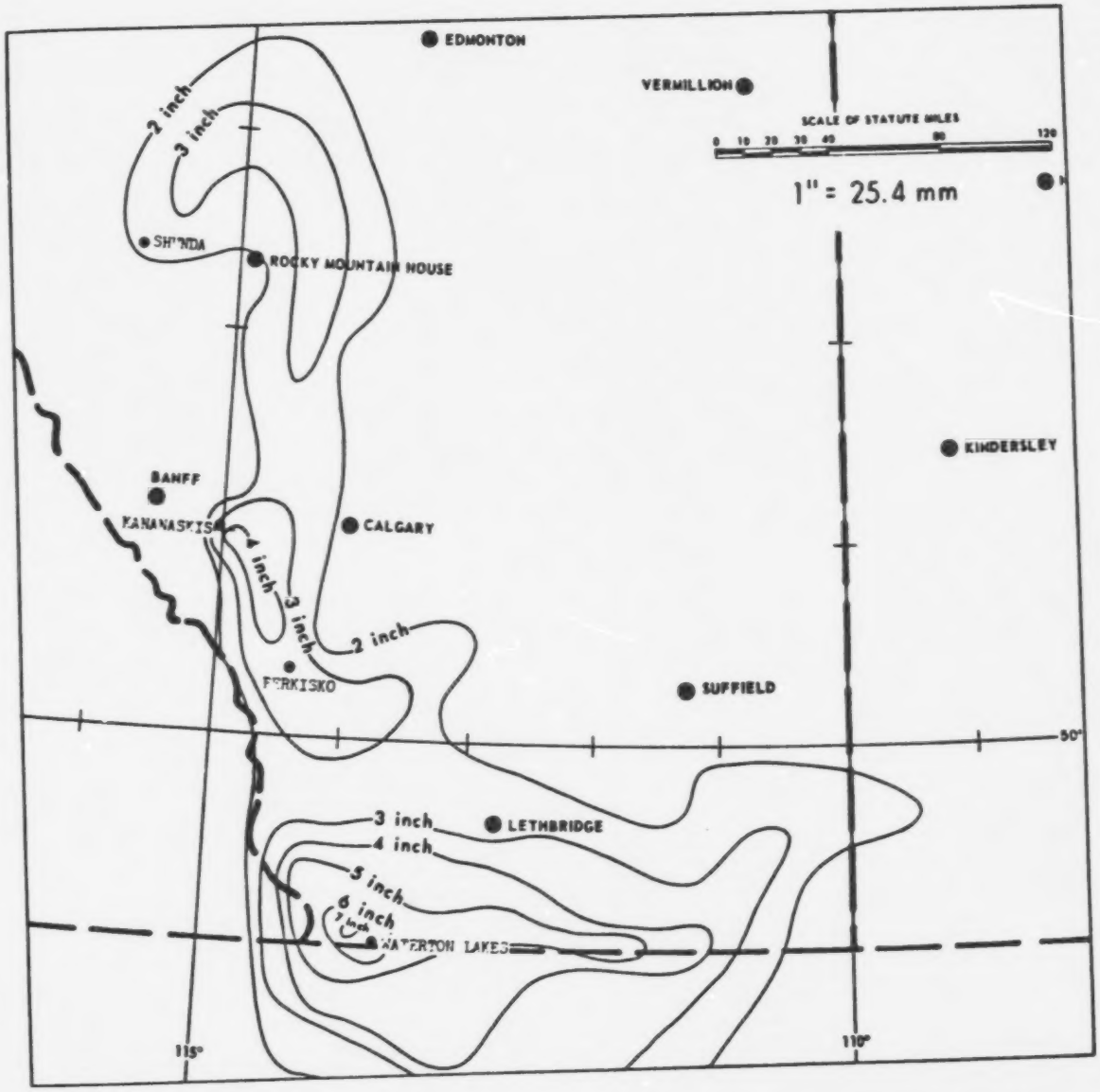
NUMBER OF RECORDING RAIN GAUGES:
NOMBRE DE PLUVIOGRAPHES: 8

SCALE OF ISOHYETAL WORK CHART: 1" = 40 STATUTE MILES
ÉCHELLE DE LA CARTE EMPLOYÉE POUR L'ANALYSE DES ISOHYÈTES: 1" = 40 MILLES TERRESTRES

FIGURE 5

ISOHYETAL CHART

CODE NO:
ALTA-5-64



RAIN GAUGE DENSITY (SQ. MI./GAUGE) FOR STATED ISOHYET 7"-0, 6"-250, 5"-410, 4"-340, 3"-400, 2"-270

NUMBER OF RECORDING RAIN GAUGES: Four

SCALE OF ISOHYETAL WORK CHART: 1"-40 Statute Miles

FIGURE 6

ROAD CROSSING MC0901

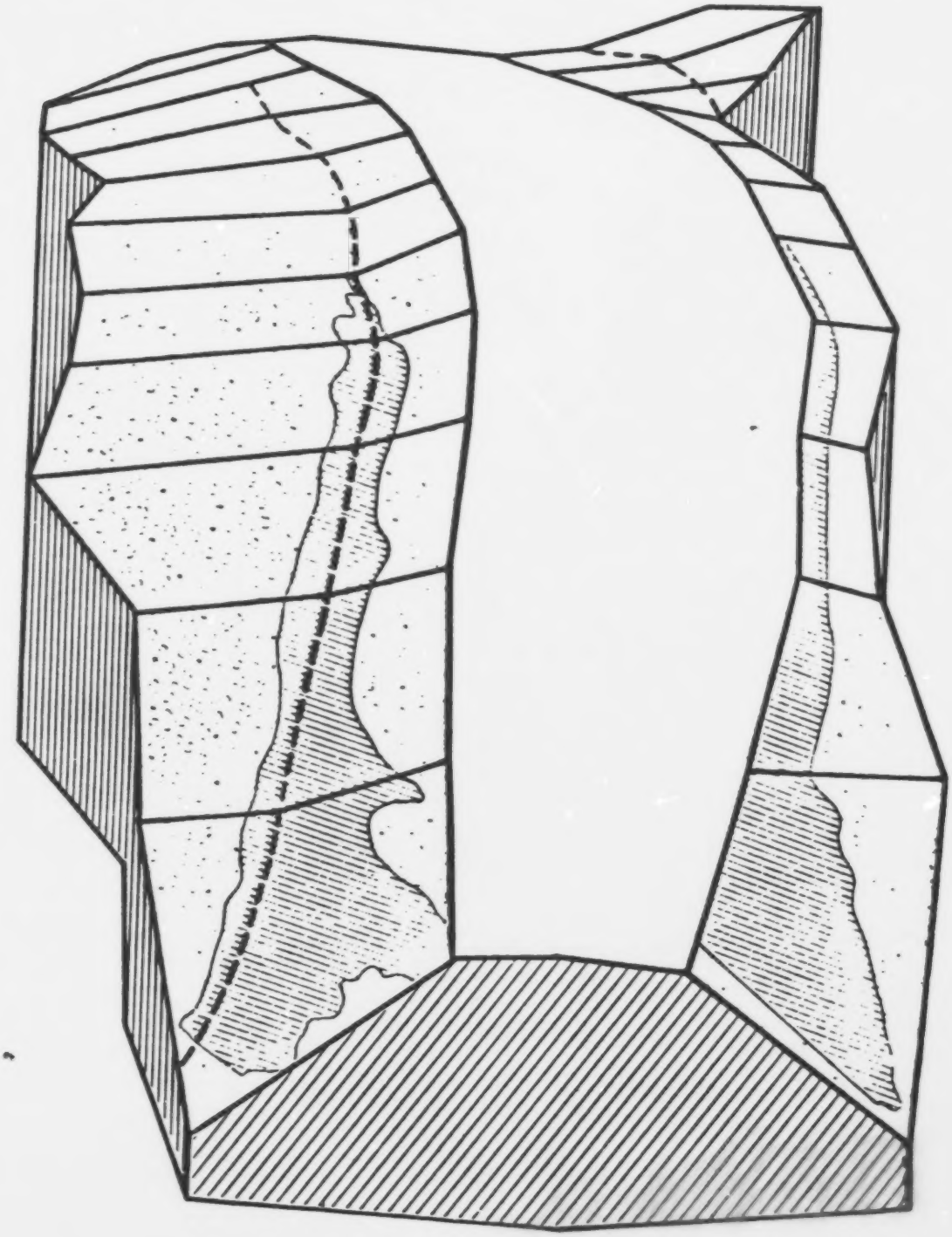


Figure 7

Soil Disturbance	ANSWERS - (areal nonpoint source watershed environment response simulation) Construction (Dillaha 1982) WRENS - soil mass movement debris avalanche - debris flows creep debris torrents - soil lost models
Channel Routing	SSAR
Channel Floodplain analysis	Hec II

Table 3 is a list of General Simulation models that process a variety of components in the Hydrologic cycle. These were originally evaluated for usefulness in pollution modelling Grimsrud (1979). To be good pollution models they require good hydrologic change predictability as well.

In light of recent advances in modelling the various components in the hydrologic cycle, an overall procedure for evaluating the changes in hydrologic processes due to mining practices, is the logical means of identifying mining impacts on the environment. The problem that remains is to evaluate the particular mining practice (physical plant design) on hydrologic processes rather than the other way around, of test designs against unexpected hydrologic processes.

CONCLUSIONS

The mining process has a great impact on the local hydrologic cycle. Hydrologic parameters may be changed many fold by the exposure and disturbance process that take place. The magnitude and variability of individual hydrologic parameters that constitutes the cycle are important points to consider in establishing mining impact guide lines. But just as important in the process, is to evaluate the alteration that the hydrologic process goes through due to the mining design. It may be that the 1 in 10 natural flood under the post mining design is well over the 1 in 100 natural flood.

TABLE 3
MODEL CAPABILITIES COMPARISONS

	LAND SURFACE SIMULATION CAPABILITIES					"CHANNELS" SIMULATION CAPABILITIES			
	HYDROLOGY			WATER QUALITY		HYDRAULICS			
MODELS	PERVIOUS LANDS	IMPERVIOUS LANDS	SNOWMELT	PHYSICAL/ CHEMICAL CONSTIT.	AGRICULTURAL CHEMICALS	1 DIMENSIONAL STREAMS	UNSTRATIFIED RESERVOIRS	STRATIFIED RESERVOIRS	ESTUARIES
HSPF	X	X	X	X	X	X	X		
ARM	X		X	X	X				
NPS	X	X	X	X					
HSPX	X	X	X	X		X	X	X	
SWMM		X		X		X	X		X
QUALII						X			
SSARR	X	X	X			X	X		
USDAHL	X	X				X			
MIT MODEL	X	X	X			X			
STORM	X	X	X	X					

TABLE 3
MODEL CAPABILITIES COMPARISONS
(Continued)

	"CHANNELS" SIMULATION CAPABILITIES					POSSIBLE RUN MODES					
	WATER QUALITY					STEADY STATE		DYNAMIC EVENT		CONTINUOUS	
MODELS	BASIC PARA-METERS	SEDIMENTS	NUTRIENTS	ALGAE	PH	HYDROLOGY	WATER QUALITY	HYDROLOGY	WATER QUALITY	HYDROLOGY	WATER QUALITY
HSPF	X	X	X	X	X	X	X	X	X	X	X
ARM						X	X	X	X	X	X
NPS						X	X	X	X	X	X
HSPX	X		X	X	X	X	X	X	X	X	X
SWMM	X		X			X	X	X	X		
QUALII	X		X	X		X	X				
SSARR						X		X		X	
USDAHL						X		X		X	
MIT MODEL						X		X			
STORM	X		X			X	X	X	X		

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Mining Effects on Surface Hydrology, Frank Davies, Alberta Environment

G. BECKSTEAD

You touched on the area of clearing or removal of vegetation, but what happens when someone digs a pit and puts on a waste dump? Do you have any site-specific answers in what changes there are in the runoff co-efficients, or are they still just going to textbooks and gathering answers that are guestimates and using them as a design?

F. DAVIES

I think that's what's happening in the industry. There are some things you can do in the field, like look at the changes of permeability. I think one thing you should understand about is frequency analysis - that is how much data are you placing your analysis on? For example, there is an experiment on frequency analysis that took a basin and a 25 year interval of 1000 years of generated data. The statistical frequencies are in the order of magnitude of 2.

P. ZIEMKIEWICZ

There are two things we have to determine:

1) We have to find out what historical storm intensity to base our estimates on. This may be anything from 1-10 year intensity to the 1-100 year intensity.
2) What is our runoff multiplier factor from the natural landscape to the mining situation? I think we must come up with some estimates on this.

F. DAVIES

I've given you what I consider a realistic example in the change of about 25% hydrologic outputs from clearing the vegetation. Putting a mining operation on it - simply from The physical change that you've done to the system would increase outputs in the order of 5 to 10 times. If you did not take this into consideration in your design criteria, you would be under-designed.

The factors are 1) drop in permeability and, 2) change in concentration of watershed on your spoils.

L. JACKSON

Just as a basis of comparison, how much greater would be the runoff in a city (like Edmonton) as compared to a natural area? Are you looking at the runoff characteristics of a semi-paved area?

F. DAVIES

You are moving into that. I looked at a picture - The relationship of the compound to the mining area, to the buildings and to the site. There was a paved parking lot up on the slope of the hill - there was a building area then a mining area below, then a small pond down below. The change in permeability from the parking lot to the building area to the exposed mining area would give you almost the entire range of things you could come up to. They are considerably different. The estimate for construction sites for soil losses is in the order of (from tree to pasture to construction) is 1 to 20 to 2000. I though that was harsh, so I looked up what happened in the Spring Creek Watershed Basin. They have been operating since 1966. They started water sampling in 1967. Then in 1977 (10 years later), a pipeline was put across the bottom of the basin. Then a full scale sediment study was done. The results showed 2.4% of the area produced 90% of the sediment and the pipeline was producing 825 times the sediment than the immediate upstream area of the basin. Those orders of magnitude and the pressure of the change in the hydrologic cycle are large.

WATER MANAGEMENT

AT CARDINAL RIVER COALS LTD.

as presented by

G.B. Acott, Environmental Co-ordinator

to a

Workshop on the Effects of Mining on

Hydrology of the Eastern Slopes

on

December 13, 1982

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1.0 INTRODUCTION

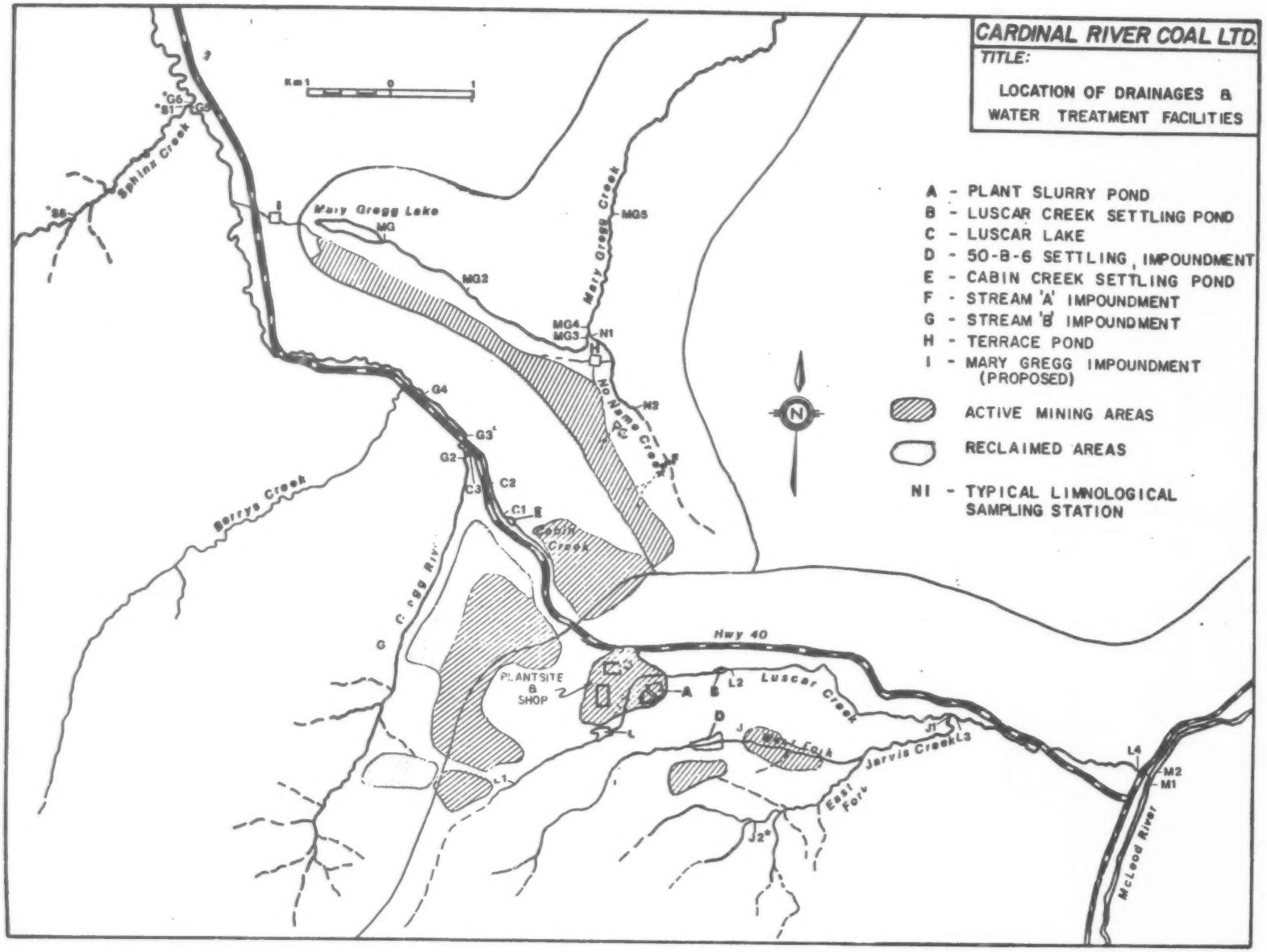
Cardinal River Coals Ltd. is a metallurgical coal mining operation located near Cadomin, Alberta, 50 km south of Hinton on Highway 40. The area lies on the Eastern Slopes of the Nikanassin Range between the elevations of 5400 - 6000 feet ASL.

Coal extraction is achieved using conventional open pit methods. Rock above the coal is drilled and blasted, then removed in progressive benches by trucks and shovels. Current operations have the capacity to remove and process 3.3 million clean short tons per annum of Sub-Bituminous B high volatile coking coal. The majority is purchased by Japan for use in the manufacture of steel. The mine currently employs some 650 individuals.

The area is subjected to a cool moist Montane climate characterized by cold, relatively dry winters with intermittent chinooks and cool, wet summers. An average of 870.8 mm (34.28 in) of precipitation is experienced per year, approximately 75% of that total as rainfall between May and September.

Mining activities in the area affect three watershed systems, all of which drain to the MacLeod River. Figure #1 illustrates these drainage basins and the areas affected within each. Also depicted are the water clarification facilities which have been constructed to maintain high quality discharge to the natural watercourses.

FIGURE #1


CARDINAL RIVER COAL LTD.
TITLE:
LOCATION OF DRAINAGES & WATER TREATMENT FACILITIES
A - PLANT SLURRY POND
B - LUSCAR CREEK SETTLING POND
C - LUSCAR LAKE
D - 50-B-6 SETTLING IMPOUNDMENT
E - CABIN CREEK SETTLING POND
F - STREAM 'A' IMPOUNDMENT
G - STREAM 'B' IMPOUNDMENT
H - TERRACE POND
I - MARY GREGG IMPOUNDMENT (PROPOSED)
ACTIVE MINING AREAS
RECLAIMED AREAS
N1 - TYPICAL LIMNOLOGICAL SAMPLING STATION
Km 1 0 1
Mary Gregg Lake
MG
MG2
MG3
MG4
MG5
Mary Gregg Creek
No Name Creek
N1
N2
G4
G3
G2
C3
C2
C1
Cabin Creek
Berry Creek
Hwy 40
PLANTSITE & SHOP
A
B
L2
Luscar Creek
D
L
J
West Fork
J1
Jarvis Creek
L3
L4
M2
M1
East Fork
J2
McLeod River
L1
S6
S1
G6
G1

2.0 IMPOUNDMENT DESIGN CRITERIA

Impoundment sizing at Cardinal River Coals Ltd. is in accordance to the methodology recommended by the United States Environmental Protection Agency. This procedure considers the Critical Settling Velocity of the sediments in relation to the efficiency of the pond.

2.1 Assumptions

Design is based on the assumption that the impoundment will naturally settle particle sizes of 20 microns (medium silt) and greater during a 1:10 year storm peak instantaneous discharge. Although Alberta Environment generally prescribes the removal of 15 micron particles and greater during a 1:10 year storm maximum daily average discharge, experience has shown that these flow rates are often exceeded. Furthermore, effluent released from mining activites often carry relatively high rates (up to 20%) of clay sized particles and flocculation is required to effectively clarify the discharge. The variation in particle size becomes immaterial if flocculation is employed.

2.2 Calculation of Inflow Rate

Rates of peak instantaneous flows are derived by utilizing a time of concentration within the Rational Formula as follows:

$$Q = 0.0028\ C_{itc}A$$

where Q = inflow rate in m^3/sec

C = catchment factor

itc = maximum rainfall intensity over the time of concentration in mm/hr

A = area of the basin in hectares

Catchment factor is largely determined through textbook values at the present time. However, streams in the area are being monitored to calibrate flow rates prior to mining. The monitoring will continue during the mining activities and throughout the reclamation sequence to evaluate the additional volumes of runoff and response times. This information will be invaluable in future planning of mine drainage.

Rainfall intensity has been based on the meteorlogical information collected at the minesite since 1971. The station consists of:

i) a tipping bucket raingauge with drum recorder
ii) a recording anemometer
iii) a maximum-minimum thermometer

Snowfall depth is measured after each event while water equivalent is determined through the installation of a heat source to the raingauge. The length of record has allowed the utilization of this data to create intensity-duration curves for various recurrence periods.

Generally included in the total inflow is an estimate of nominal groundwater flows into the pit within the drainage area. The estimates are generally based on experience in previous pits, pre-mining groundwater investigation studies and the type of geology to be encountered.

2.3 Impoundment Sizing

The surface area of the treatment facility is determined by comparison of the calculated inflow rate and the settling velocity. A 20% safety factor is generally added for non-behavioural conditions which may occur within the pond (turbulence, short circuiting, etc.) as the sizing concept assumes ideal settling conditions.

Depth or storage volume is a function of the amount of sediment which will be carried by the inflowing water, rate of bedload transport and the frequency with which dredging will be conducted. It is normally more economic to increase initial volume than to plan on frequent dredging.

3.0 FLOCCULATION

Cardinal River Coals Ltd. has installed and is currently operating four flocculation systems. Polyelectrolytic flocculant is added to inflow in a two stage process based on volume of flow and sediment load. The cationic chemical effectively neutralizes the negatively charged sediments and causes the agglomeration of particles around a positively charged centre. Anionic flocculant is added immediately prior to entrance of the inflow to the treatment facility, serving to collect the agglomerates to larger, more dense particles which settle instantly in calm water.

3.1 Problem Areas

Operation over the past three years have shown flocculation to be highly effective. However, the following problems should be identified:

i) Initial set-up cost - specialized equipment including tanks, mixers and feed pumps are available from numerous retailers, but costs are somewhat exorbitant. Small buildings are required for each of the cationic and anionic addition points which must be serviced with electricity, heat and water. Cardinal River Coals Ltd. has been successful in reducing these costs by fabricating some of the more standard types of equipment, constructing the buildings on site and utilizing generators in remote areas. In addition, mix water is usually hauled by mine equipment which eliminates the need for a well and submersible pump.

ii) Operation is time intensive - with four active systems, an intensive manpower allotment is required to:
- haul mix water
- ensure adequate supplies of raw chemical are available at the stations (chemical supplied in liquid form in 45 gallon drums)
- calculate polymer concentration and mix accordingly
- maintain access for water truck through winter periods.

Although automatic mixing systems are available, the equipment is extremely expensive. In addition, an on-demand water system is required and the raw chemical supply must be maintained.

iii) Doseage rates - chemical feed rates are, at present, set by manual methods based on flow (or pumping rate) and the sediment load. The individual draws heavily on past experience and jar tests in the laboratory continue regularly but, to a certain extent, an element of trial and error remains. Overdoseage can waste chemical while underdoseage runs the risk of exceeding effluent discharge standards. Additionally, manual adjustment of feed rates can be very inconvenient if inflows vary during periods when staff are not on site.

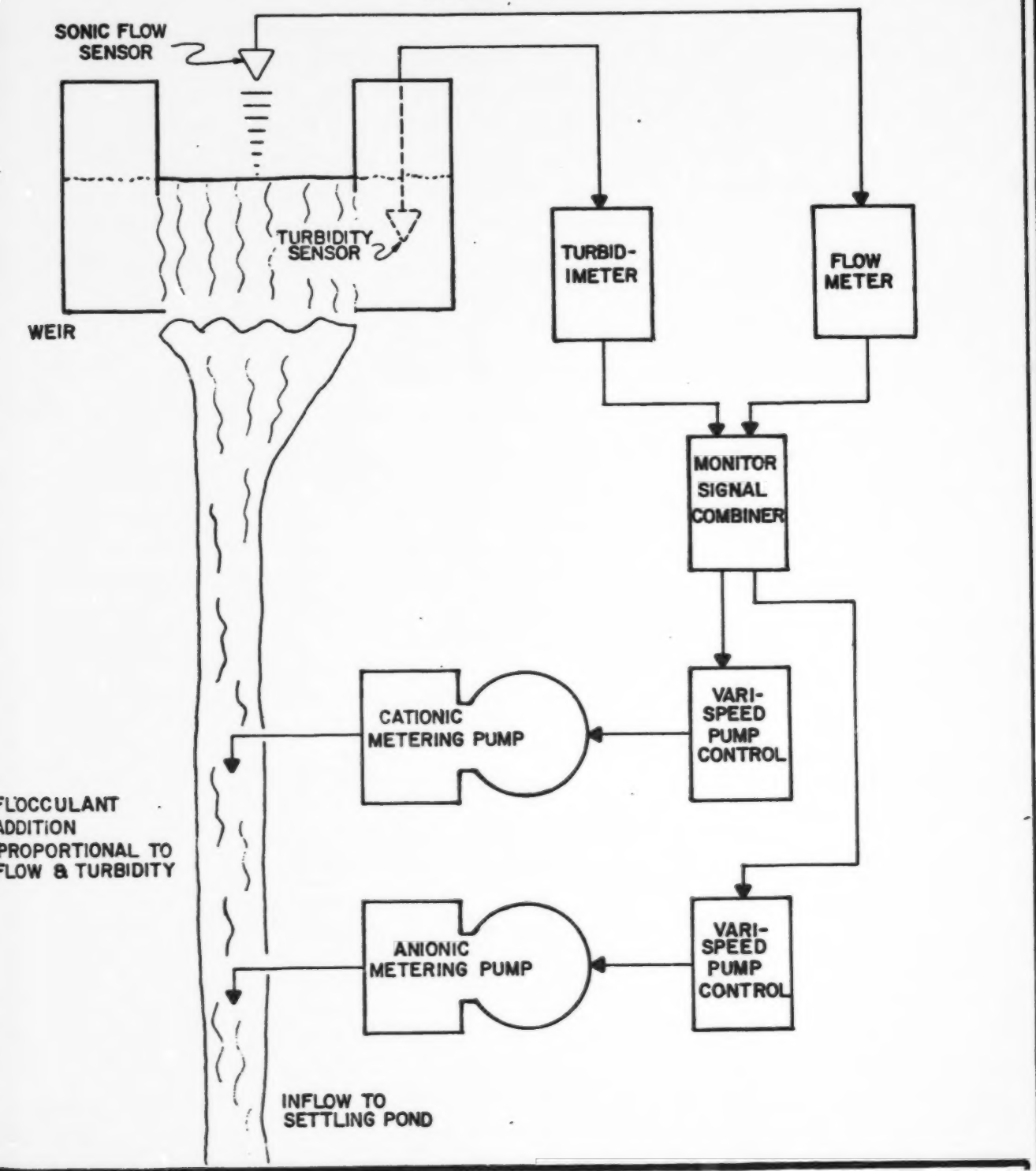
Subsequently, Cardinal River Coals Ltd., in affiliation with an equipment supplier, are developing a prototype Automatic Feed System as depicted in Figure #2. Flows are directed through a flume equipped with a water level sensor to determine flow rate. A portion of the flow is directed through an industrial turbidity meter to evaluate sediment load. A signal combiner assesses information received from these sources and adjusts the variable speed feed pumps to add the polymer in the correct quantities.

3.2 Flocculant Toxicity

Chemically refined flocculants, by virtue of their electrolytic characteristics, may have an adverse impact to the biological community when added to clear water. The cationic product, in particular, has a greater affinity for the oxygen exchange mechanism (i.e. gill of a fish) then does oxygen. The flocculant does, however, have a greater affinity for any sediment which is present in the water and, therefore, causes no toxicity problems when correctly administered.

Figure #3 shows the toxicity rating on each of the Calgon and Cyanamid products used at Cardinal River Coals Ltd. (Cationic addition rates over the past 3 years have ranged between 2 and 20 mg/litre while anionic has varied between 0.5 and 2 mg/litre.) The 96 hour bioassays are conducted with the chemical added to clear water which should never

FIGURE #2



CARDINAL RIVER COALS LTD. LUSCAR ALBERTA		
DESIGN BY: M.O'T	TITLE : AUTOMATIC FLOCCULANT FEED SYSTEM	SCALE:
DWN. BY: LG.		DATE:
APPROVED BY:		DWG. NO.

FLOCCULANT TOXICITY DATA

96 HOUR STATIC FISH BIOASSAY

CHEMICAL NAME	CHEMICAL TYPE	CHEMICAL CONCENTRATION	TEST SPECIMENS	MORTALITY
MAGNIFLOC 587C	CATIONIC LIQUID	3.0 MG/ℓ	RAINBOW TROUT	0%
MAGNIFLOC 577C	CATIONIC LIQUID	2.1 MG/ℓ	RAINBOW TROUT	LC 50*
CALGON CATFLOC T-1	CATIONIC LIQUID	0.22 MG/ℓ	RAINBOW TROUT	LC 50
MAGNIFLOC 1849A	ANIONIC EMULSION	75.0 MG/ℓ	RAINBOW TROUT	0%
CALGON L 690-E	LIQUID ANIONIC	> 500.0 MG/ℓ	RAINBOW TROUT	LC 50

* LC 50 - THE LETHAL CONCENTRATION AT WHICH 50% OF THE SAMPLE POPULATION ARE DESTROYED THROUGH A 96 HOUR PERIOD.

FIGURE #3

be the case in the field. Additionally, the flocculant is added to an inflow from a disturbed area, allowed to settle for a variable time period, then released to a natural watercourse with a flow rate many times greater. The sediment load, settling time, and dilution effect are more than adequate, in the majority of situations, to eliminate any harmful effects which could potentially be caused through the utilization of flocculants.

4.0 WATER MONITORING PROGRAM

In accordance with the terms and conditions as contained in our Clean Water Licence to Operate, the water monitoring programs, as outlined in Figures #4 and #5, have been initiated.

Regular samples are now being analyzed by qualified personnel within our mine site laboratory while detailed samples are forwarded to a commercial laboratory.

FIGURE #4

CARDINAL RIVER COALS LTD.

REGULAR WATER SAMPLING PROGRAM

ANALYSIS PARAMETERS	MAXIMUM ACCEPTABLE LIMIT
TOTAL SUSPENDED SOLIDS	50 mg/ℓ ABSOLUTE 10 mg/ℓ OVER NATURAL BACKGROUND
TOTAL DISSOLVED SOLIDS	
pH	6.5 - 9.5
TURBIDITY	
TOTAL IRON	3.5 mg/ℓ

SAMPLING SCHEDULE

I) APRIL THROUGH OCTOBER

ONE 24 HOUR COMPOSITE SAMPLE PER WEEK FROM:

Cabin Creek Settling Pond
Luscar Creek Settling Pond
Terrace Settling Pond
50-B-6 Settling Pond
Mary Gregg Creek
No Name Creek

ONE GRAB SAMPLE PER WEEK FROM:

- Gregg River Upstream

II) NOVEMBER THROUGH MARCH

ONE GRAB SAMPLE EVERY TWO WEEKS FROM:

All Settling Ponds Listed Above

FIGURE #5

CARDINAL RIVER COALS LTD.

DETAILED WATER SAMPLING PROGRAM

ANALYSIS PARAMETERS

TOTAL ORGANIC CARBON	pH
VOLATILE SUSPENDED SOLIDS	Hg
VOLATILE DISSOLVED SOLIDS	Cd
CALCIUM	Mn
SODIUM	As
SiO_2	Al
NO_3-N	Zn
NH_3-N	Pb
TOTAL KJELDAHL-N	Cu
SO_4	B
F	

SAMPLING SCHEDULE

ONE GRAB SAMPLE FROM EACH LOCATION IN THE FOLLOWING MONTHS:

APRIL

JULY

OCTOBER

5.0 TREATMENT FACILITY MAINTENANCE

Deposition of sediment in a pond or impoundment will gradually reduce volume and, eventually, surface area. This severely impairs the effectiveness of the facility and jeopardizes water quality in the receiving streams.

Cardinal River Coals Ltd. conducts an annual survey in each settling impoundment to determine the depth of accumulated sediment and the subsequent reduction in volume. As a facility approaches 65% of design capacity, plans are made for dredging by one of two methods.

5.1 Excavation

Water levels in the pond are reduced during early winter when flows have subsided. A dragline or backhoe is then utilized to remove the deposited material. The sediment is loaded into trucks and transported to an active dump for disposal. The dirty water created during the dredging operations is held within the pond until the original water level has been attained.

High water content substantially reduces the capacity of the trucks and necessitates the use of chains and boomers to keep tailgates closed. Leakage results in very slippery haul roads and a corresponding increase in road maintenance. These factors contribute to a very high per yard removal cost.

5.2 Mudcat Dredge

Another alternative which is feasible in certain situations is the use of a floating dredge. The machine floats on the surface of the water while lowering an adjustable "cutting drum". The drum rotates, agitates the sediment and removes the material through suction from a powerful pump. Material is pumped to a disposal site where it may settle and clarified water may be pumped from the surface at a later

date. Sediment slurry which is removed is generally about 20% solids.

Certain problems are also associated with this method. Firstly, and most importantly, a tremendous volume of slurry is removed from the pond and a large disposal site is essential. Cardinal River Coals Ltd. has been able to use abandoned pits for disposal, but these areas are not always available. Secondly, because the discharge is 80% water, some inflow is usually required to keep the pond from going dry. This problem may be overcome through recirculation.

Costs of dredging by this method are generally about 20-30% less expensive than through excavation and provide a more flexible timetable for undertaking the work.

6.0 CONCLUSION

The extraction of coal by conventional surface methods affects a large surface area. Along the Eastern slopes, this activity may result in disturbance of a number of small watersheds; the maintenance of water quality throughout the operation becomes the primary environmental concern.

Cardinal River Coals Ltd. has learned that forethought and preplanning of water control facilities is absolutely imperative and that implementation of these proposals is necessary prior to the commencement of mining operations. Research on improving water quality and alleviating some of the operations problems associated with the clarification process must be continually on-going to more effectively deal with the problems.

Water Management at Cardinal River Coal

G.B. Acott

L. JACKSON

What's the water quality like coming out? You said you were running regular analyses of water chemistry effluent. Have you any problems besides your intermittent mercury problem?

G. ACOTT

In terms of actual detail, not too much. We did have a problem a while back with zinc, which we attributed to a faulty culvert that we had. The greatest emphasis of our water clarification program is towards suspended solids. Nitrates are a concern as well.

CALCULATING FLOOD FREQUENCIES AND VOLUMES

Prepared by:

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CALGARY, ALBERTA.

Prepared for:

EFFECTS OF MINING ON HYDROLOGY OF THE EASTERN SLOPES

A WORKSHOP ORGANIZED BY THE RECLAMATION RESEARCH TECHNICAL ADVISORY COMMITTEE, ALBERTA ENERGY AND NATURAL RESOURCES

DECEMBER 13, 1982

EDMONTON, ALBERTA.

ABSTRACT

This paper discusses the need for hydrologic studies and the commonly used methods for calculating flood-frequencies and volumes. The selection of appropriate design criteria is presented and related to the design life of a structure and the risks that are allowable in selecting design parameters. The use of hydrologic studies is examined as it related to a level of effort required to produce the flood estimates and the potential savings that may accrue. Data sources are reviewed which are useful in the calculation of hydrologic parameters. Methods of calculating flood frequencies and volumes are discussed and advantages and disadvantages of each are listed. Methods presented include transfer methods, empirical methods (rational formula), the unit hydrograph and regional analyses such as the index flood method, multiple regression of floods and volumes and multiple regression of the frequency function moments.

1.0 INTRODUCTION

1.1 HYDROLOGIC STUDIES

-To date hydrologic calculations for mining development have too often been over or under conservative probably because of the use of simplistic methods in a very complex hydrologic region.

-Before we go into the methods available and complexities of the regions to be dealt with, lets establish why we need to calculate flood peaks and volumes.

1) Mining developments in East Slopes are at or near headwaters of streams which will be diverted or whose flow regimes will be altered (as discussed by Davies - Mining Effects on Hydrology).

2) The mine hydrologist has to design for:
   -crossings (road and rail)
   -water intake/supplies
   -diversions
   -surface water and sediment control measures (ditches and ponds)

3) Adequately designed works can:
   -prevent shut-downs due to environmental or structural failure
   -reduce maintenance costs
   -improve operations efficiency

1.2 DESIGN CRITERIA

-Before you undertake a hydrologic analysis you have to assess what information you need. i.e. what is your Design Criteria?. This is established based on 1) governments regulations and guidelines - these are only guidelines to give you a start. 2) what are the risks? - shut downs or loss of life or equipment damage ($) and potential impacts? - pollution, fisheries, flooding downstream, erosion, etc. 3) what is the cost of going to a higher design level benefit/cost analysis - (highly subjective). Therefore the hydrologist should sit down and discuss suitable design criteria with mining engineers, environmental planners and designers.

1.3 DESIGN LIFE

1) why design a ditch system with culverts and road crossings for a 1:100 year flood when its going to be mined out in 2-5 years? The risk or probability that a 100-year flood will occur in 5 years is 4.9%, as given in Table 1 below:

TABLE 1

Required return periods in years, corresponding to different levels of acceptable risk for different service periods.

Risk	Service Period					
	2	5	10	20	50	100
0.99	1.1	1.7	2.7	4.86	11.4	22.2
0.75	1.7	4.0	6.7	14.9	35.6	72.7
0.50	3.4	7.7	14.9	29.4	72.6	144.8
0.40	4.0	10.3	20.1	39.7	98.4	196
0.30	5.7	14.5	28.5	56.5	141	281
0.20	9.0	22.9	45.3	90.1	225	449
0.10	19.5	48.1	95.4	190	475	950
0.05	39.5	98	195	390	976	1949
0.01	198	498	996	1992	4975	9953

2) if you have a diversion and/or a dam above a pit with a $20 X 10^6 dragline and workers in it, are you going to design for a 10 year flood?

1.4 LEVEL OF EFFORT

Now - decide what level of effort is required.

1) if you're sizing a culvert for a ditch draining a few hectares you're not going to spend $20,000 on a hydrologic study. However if you're developing a hydrologic design methodology for the entire mine or designing a major dam or river diversion - spending $20,000 or $30,000 on a detailed hydrologic analysis could save you that amount many times over in materials and construction costs.

2) a properly conducted study (using all information available, whether qualitative or quantitative) will provide much greater confidence in your results and eliminate the need for 'fudge' factors or overly conservative and needlessly expensive designs.

3) potential impacts (environmental damages) will be minimized, and maintenance and repairs reduced due to failures as a result of poor design and planning. A properly designed and planned water management program at the start will reduce many headaches down the road!

2.0 DATA

-What data is required to determine peak discharges and volumes?
-Water Survey of Canada - discharges, elevations at gauging sites.
-Atmospheric Environment - precipitation - short duration rainfall - intensity - duration frequency curves.
-Regional/local/private studies (other mines, government, forestry).
-Energy Mines & Resources - topographic maps - air photos.
-Alberta Forest Service - vegetation, research basins.
-Alberta Research Council - hydrogeology - soils - surficial geology; high water levels, hydraulic data.
-Geologic Survey of Canada - geology.
-Alberta Environment - flood studies, high water marks, river regime studies.
-Often available data is too general, site-specific geology and vegetation information required is generally available since other aspects of the development requires it; i.e. Reclamation studies and groundwater/geologic studies for mine design.
-Data, while it appears adequate, may not be applicable to your needs; i.e. short duration rainfall-intensity frequency curves. Duration curves are available for only a few stations - such as Edson. Alberta Forestry Stations take readings every 12 hours. What happens if you're 50 miles from Edson, and want a 1 or 2 hour duration rainfall intensity?

3.0 METHODS OF CALCULATING DISCHARGES AND VOLUMES

Methods will be outlined and data requirements, adaptability, limitations and problems of these methods will be discussed.

3.1 TRANSFER METHODS

This involves the direct transfer of peak flow frequency values or entire flood flow frequency functions from similarly gauged locations to the desired gauged location. Generally based on an adjustment applied to the relation of drainage area sizes, this method is valuable primarily for a quick check of the reasonableness of other procedures, both for the magnitude of selected events and for the slope of the resulting derived flood flow frequency function.

Applicability/Advantages

Procedure is easy and quick to use.
Provides reliable estimates if hydrologic characteristics are consistent.

Procedure is commonly used and generally accepted.
Can readily be used as a check for reasonableness of results from other procedures.
Provides valuable insight as to the regional slope characteristics of the flood flow frequency relationships.

Limitations/Disadvantages
Procedure's ease of use may result in improper application.
Estimates are not accurate enough for most analysis requirements.
Cannot be used for modified basin conditions.
Can only be used as check in areas where hydrologic characteristics are nearly similar and with drainage areas within the same order of magnitude.

3.2 Empirical Methods

Rational: Q=CIA
where C = Runoff Coefficient
I = Rainfall Intensity
A = Drainage Area

-Widely used because of simplicity - but often wrongly used. It's use is probably many times that of all other procedures combined.
-Developed primarily for analysis of small urban areas.
-intended only for small areas: applicable only when duration of the rainfall is equal to (or greater than) the time of concentration of the watershed; if not-overestimates
-volumes - assume that the peak is reliably obtained.
- use time of concentration, duration of rainfall, length of runoff period, and establish triangular hydrograph(s) to obtain runoff volume, Drawing 1.
- poor estimate of runoff volume.

Need:
1) drainage area (topographic maps)
2) rainfall intensity
- assume frequency of rainfall is identical to frequency of runoff, Drawing 2A
- not easily transferred from AES meteorological stations
- affected by elevation, regional terrain, storm patterns, etc. (All of these factors are highly variable along the eastern slopes), Drawing 2B
3) runoff coefficient - percent of total rainfall that runs off, i.e. excess rainfall (deletes evapotranspiration, infiltration, storage, interception, etc.) based on vegetation, soil type, land use, degree of imperviousness, watershed slope, recurrence interval. C changes with time (seasonal).
- a factor which accounts for the lumped effect of the physical characteristics of the basin.
- adaptability - change "C" - mined/unmined.
- drainage ditches change time of concentration and C

Applicability/Advantages
Provides quick means of estimating peak discharge frequency for small areas.
Concept can be understood by nonhydrologists.
Suitable for many types of municipal engineering analyses (storm sewers, culverts, small organization impacts).
Familiarity of procedures and use has led to politically acceptable solutions for small areas.
Flood flow frequency relationships.
Can be used as a check for reasonableness of more applicable procedures in small areas.

Limitations/Disadvantages

Generally not applicable for areas greater than one square mile.
Estimate only the peak discharge relationships; poor estimator of volume.
Cannot be used to design storage facilities.
Cannot adequately evaluate complex systems where timing and combining of flood hydrographs are important.
Does not include effect of snowmelt, which may result in peak discharge on small basins in the East Slopes.

3.3 UNIT HYDROGRAPH METHOD

-based on theory that hydrograph shape is the same for a particular basin and can be enlarged.
-gives hydrograph for a unit amount of runoff (1") which is enlarged or reduced accordingly.
-used in Soil Conservation Service method, Drawing 2C.
-numerous computer models are available: HEC-1 and HYMO (uses SCS method)
-problem is generally in calibrating, establishing hydrograph shape and input data required:
  -time of concentration and runoff curve number
-also requires rainfall (generally assume rainfall is distributed in the same temporal and spatial pattern for all storms) - often an unrealistic assumption
-gives directly the peak flow and volume and is good for flood and storage routing.
-the SCS and HYMO methods involve only rainfall runoff - what about snowmelt or rainfall combined with snowmelt, as is common on the eastern slopes? The HEC-1 model includes a snowmelt runoff estimation.

Applicability/Advantages

Generates other hydrologic information rather than only peak discharges (volumes, time to peak, rate of rise, etc.).
Generates balanced floods as opposed to historically generated events which may be biased.
Enables evaluation of complex systems and modifications to the watersheds.
Provides good documentation for quick future use.
Uses fewer parameters than most continuous simulation models.
Approximates the hydrologic runoff process as opposed to statistical methods.
Procedures are more economical than continuous simulation procedures.
Calibration procedures are easier than continuous simulation models.
Models may be calibrated to either simple or complex systems.

Limitations/Disadvantages

Balanced flood concept is difficult to understand.
Modelling requires more time, data, resources (costs) than statistical procedures.
Hydrologists must understand the concepts utilized by the model.
Requires calibration to assure rainfall frequency approximates runoff frequency.
Unit hydrograph assumes linear relationship with runoff.
Requires data processing capabilities.
Procedures greatly simplify the hydrologic process.
Procedures are generally limited to basins greater than one square mile.
Parameters are difficult to obtain for existing and modified conditions.
Difficult to obtain antecedent moisture conditions.
Depth-area of rainfall varies with drainage area size.

3.4 REGIONAL FLOOD/VOLUME FREQUENCY ANALYSES

Relates peak runoff or peak volume to site based on physical characteristics

3.4.1 Index Flood Method

Crudest method is index flood method

- -Uses regression relation to determine mean annual flood based on drainage area only, Drawing 3.
- -Uses factors to determine rarer flood peaks (ratio to mean annual flood).
- -Does not predict flood volume (hydrograph analysis required).

Applicability/Advantages

Procedure is easier to develop than other statistical methods and has only one regression analysis.
Procedures are commonly used and based on accepted statistical methods.
Reliability of prediction equation for index flood is known for derivation.
Estimates are reliable for hydrologically similar basins as those used in derivation.
Once developed, the procedure is quick and easy to use.
Procedures may be used in conjunction with other procedures to provide calibration results for simulation models.
Provides a quick check for reasonableness for situations requiring use of other procedures.

Limitations/Disadvantages

Procedure yields same variance (slope of frequency curve) for all applications.
Probably least accurate of the statistical procedures.
Requires knowledge of both statistics and hydrology in derivation and utilization.
May be time consuming to develop.
Only provides estimates of peak flood flow (or volume) frequency relationships.
Cannot evaluate effects resulting from major modifications in the system (physical works and alternative land use patterns).
Cannot adequately evaluate many complex river systems.
Cannot evaluate hydrologically unique areas in the region.
Ease of use may result in improper application.
Derivation requires several hydrologically similar gauged basins in the region.

3.4.2 Multiple Regression (Floods, Volumes)

Relates runoff and volumes to other characteristics of the drainage basin which are generally known to have a clear physical association with flood peaks, such as:

- -drainage area
- -area drained by lakes, or % of basin
- -aspect
- -elevation (may relate to vegetation)
- -basin slope, stream slope
- -precipitation (rainfall, snowfall)
- -basin shape
- -land use
- -soil (permeability and capacity of groundwater formations)
- -vegetation
- -etc.
- -Multiple regression is used to determine most important parameters.

-preferable to the flood index method because the resulting equations preserve the effects of differing basin features on the flood frequency regime within a particular region and average the chance variation that exists amongst a group of individual station records.

Applicability/Advantages
Procedures are based on accepted statistical methods.
Procedures are available for most of the country.
Reliability of the prediction equations is known for gauged areas used in derivation.
Estimates are reliable for hydrologically similar basins as those used in the derivation.
Once developed, the procedure is quick and easy to use.
Permits direct calculation of specific peak flood flow frequency estimates that are individually and statistically derived.
Procedures may be used in conjunction with other procedures such as to provide calibration results for simulation models.
Provides a quick check for reasonableness for situations requiring use of other procedures.

Limitations/Disadvantages
Requires knowledge of both statistics and hydrology in derivation and utilization.
Procedures require numerous regression analyses and is time consuming to develop.
Only provides estimates of specific peak flood flow frequency relationships.
Cannot evaluate effects resulting from major modifications in the system (physical works and alternative land use patterns).
Procedures are often misused by application for areas with different stream patterns and other hydrologic characteristics from the gauged locations used in the derivation.
Cannot adequately evaluate hydrologically unique areas in the region.
Easy to use and may be used where other methods are more appropriate.
Derivation requries several hydrologically similar gauged basins in the region.
Does not assume a distribution; hence reliable confidence limits cannot be calculated.

3.4.3 Multiple Regression (Moments)

An adaptation of the statistical estimation of flood peak method is to correlate the statistical moments of the frequency function at gauged locations to the ungauged locations.

The end results are prediction equations which define the moments of the estimated frequency curve at the ungauged location - thus providing the capability to derive the frequency curve directly (if the entire range of flood flow frequencies are required in the analysis).

This method has the advantages that the results are statistically based and may be expeditiously used once they are derived for a region. However, it requires a knowledge of statistics and does not generate entire hydrograph information.

Applicability/Advantages
Procedures are based on accepted statistical methods.
The entire frequency function is developed from the three moments; means, standard deviation and skew.
Reliability of the prediction equations is known for gauged areas used in derivation.

Estimates are reliable for hydrologically similar basins as those used in the derivation.
Once developed, the procedure is quick and easy to use.
Procedures may be used in conjunction with other procedures to provide calibration results for simulation models.
Provides a quick check for reasonableness for situations requiring use of other procedures.

Limitations/Disadvantages
Requires knowledge of both statistics and hydrology in derivation and utlization.
Procedure requires regression analysis for the two or three moments of the frequency function.
May be time consuming to develop.
Does not calculate specific flood flow fequency events.
Only provides estimates of peak flood flow frequency (or volume) relationships.
Cannot evaluate effects resulting from modifications in the system (physical works and alternative land use patterns).
Cannot adequately evaluate many complex river systems.
Cannot evaluate hydrologically unique areas in the region.
Ease of use may result in improper application.
Derivation requires several hydrologically similar gauged basins in the region.

4.0 SUMMARY

Prior to undertaking an analysis - design criteria and objectives should be established. Set design criteria that meet the needs of the development being planned. Determine the level of effort required for the task.

The need for "proper" hydrologic studies is evident as it can provide significant cost savings at front end (capital) and maintenance (operating costs) as well as reduce impacts and "headaches".

The present practice of using methods such as the Rational and SCS can provide very misleading results in the Eastern Slopes without properly accounting for the many complex pecularities in this area. These methods require extensive calibration to provide reliable results. They should be used with caution! These simplistic methods may be best suited to conceptual and preliminary studies.

The use of regional studies using all data available and methods which account for very extreme events should be applied, since all too often not enough site specific information is available. However, correlations with site-specific information should be undertaken in all cases.

No one method is the best. If suitable for the particular situation, several methods may be used, the results compared, and a decision made, Drawing 4.

The impact of mining (drainage systems, deforestation, pit/dump runoff) on runoff in this area is only starting to be assessed - answers will only be obtained with detailed monitoring programs. Hopefully some of the tools which are available can be calibrated and applied to this area.

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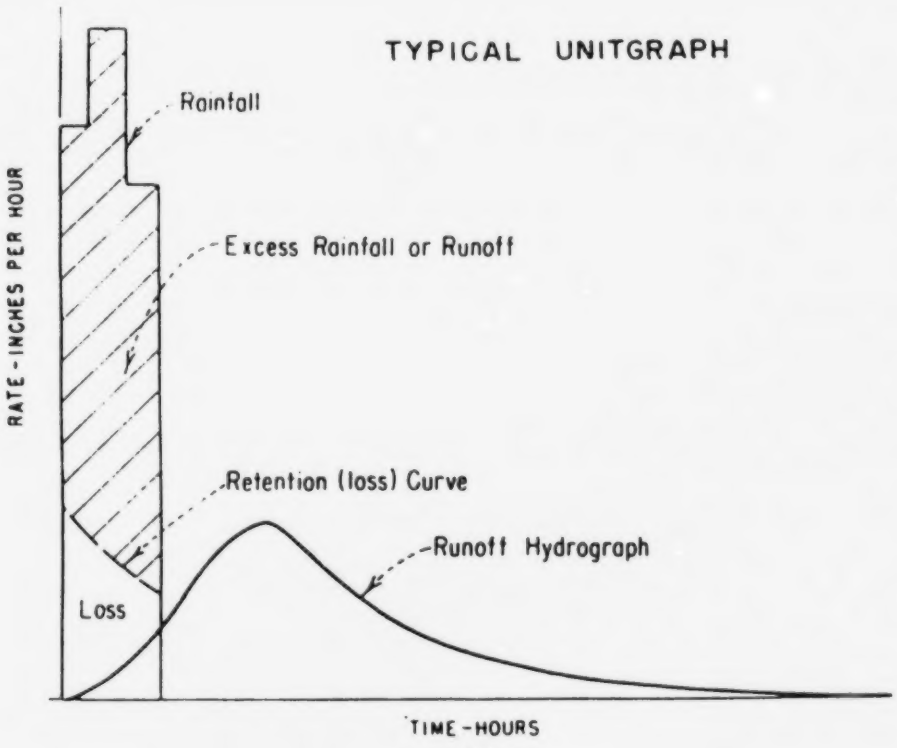
Viessman, W. Jr., et al, 1977. "Introduction to Hydrology", Thomas Y. Crowell Company, Inc.

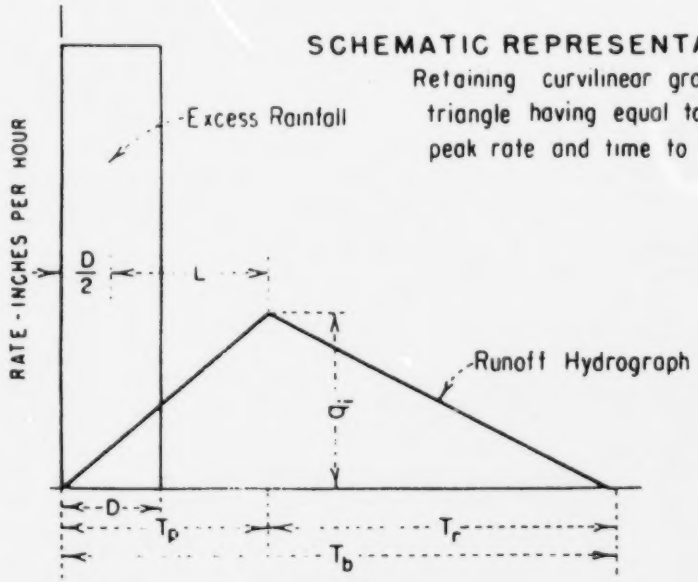
TYPICAL UNITGRAPH



(A)

SCHEMATIC REPRESENTATION OF UNITGRAPH

Retaining curvilinear graph by triangle having equal total runoff, peak rate and time to peak



(B)

FROM: " DESIGN OF SMALL DAMS "

REV.	BY	DESCRIPTION	DATE	APPR'D.
0		FIRST ISSUE		

CLIENT: MINING HYDROLOGY WORKSHOP

PROJECT: FLOOD - FREQUENCIES AND VOLUMES

SUBJECT: TRIANGULAR HYDROGRAPH ANALYSIS

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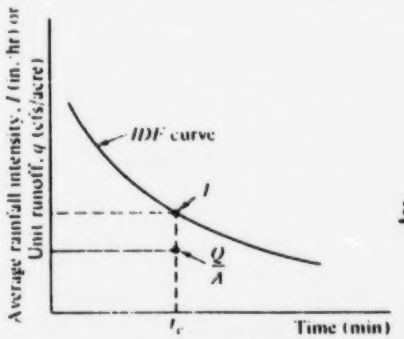
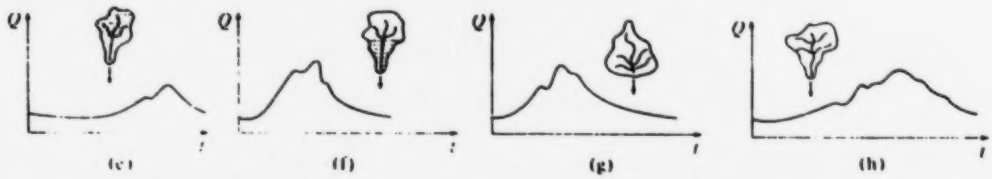
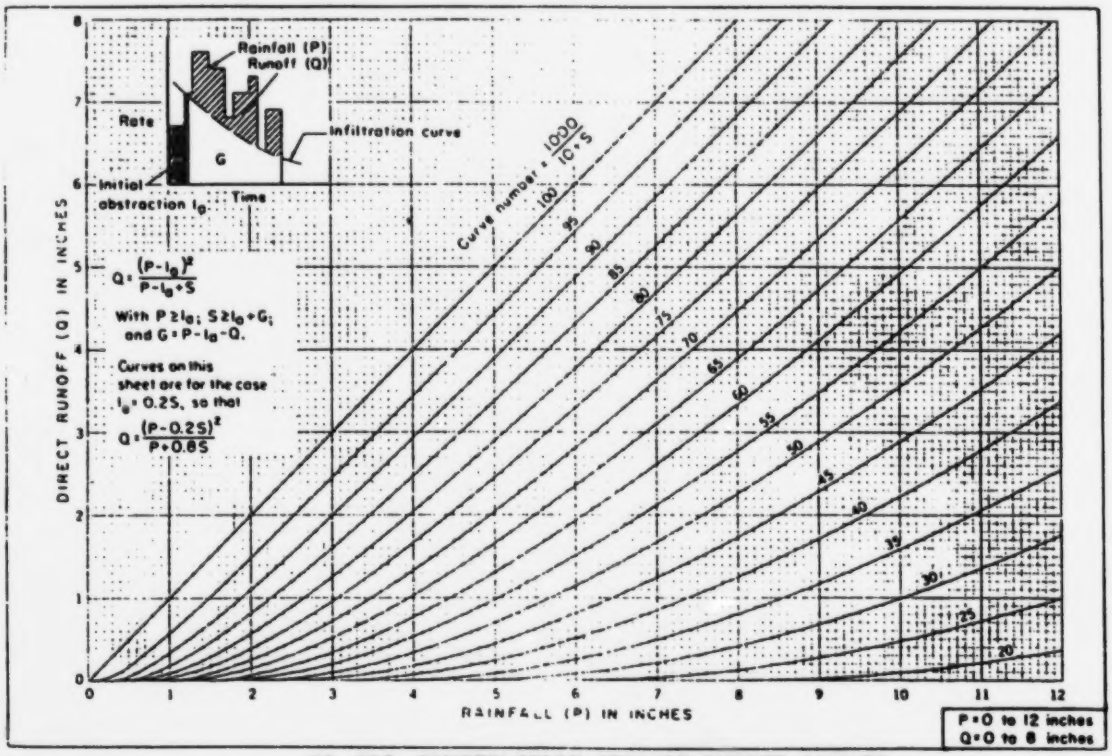


2A

Rainfall runoff relation for the Rational Method



2B EFFECTS OF STORM CHARACTERISTICS ON HYDROGRAPH SHAPE



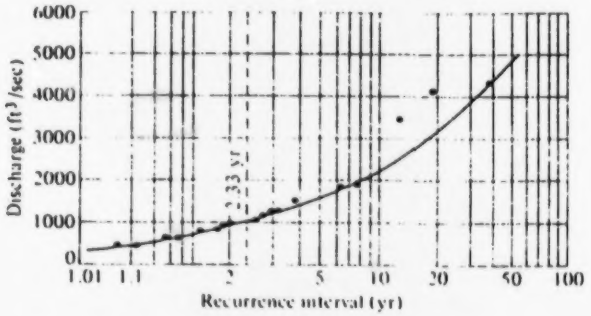
2C SOIL CONSERVATION SERVICE RUNOFF CURVES

FROM: "INTRODUCTION TO HYDROLOGY"

REV.	BY	DESCRIPTION	DATE	APP'D.
0		FIRST ISSUE		

CLIENT: MINING HYDROLOGY WORKSHOP
PROJECT: FLOOD-FREQUENCIES AND VOLUMES
SUBJECT: EMPIRICAL RUNOFF RELATION
HYDROCON ENGINEERING (CONTINENTAL) LTD
DESIGN BY | DRAWN | APPROVED | DATE | JOB No. | Sub No. 2 | REV. 0

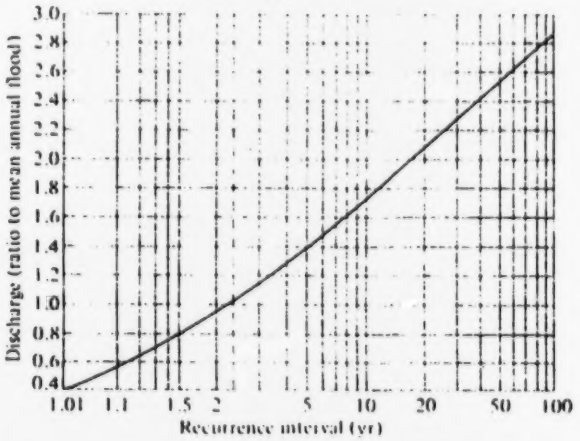
DP 001A HEL



(a)

Station	Recurrence intervals (yr)					
	1.1	1.5	5	10	20	50
1	0.49	0.73	1.46	1.93	2.55	3.03
2	0.52	0.76	1.36	1.74	2.18	2.73
3	0.54	0.79	1.42	1.88	2.39	2.89
4	0.57	0.80	1.44	1.82	1.98	2.48
5	0.56	0.79	1.34	1.63	1.87	2.12
6	0.49	0.78	1.37	1.85	1.91	2.26
7	0.50	0.75	1.34	1.70	2.08	2.47
8	0.48	0.76	1.39	1.76	2.21	2.62
9	0.60	0.83	1.47	1.90	2.38	3.00
10	0.62	0.81	1.39	1.77	2.28	2.92
11	0.58	0.78	1.42	1.87	2.30	2.90
12	0.63	0.80	1.36	1.80	2.39	3.01
13	0.47	0.74	1.41	2.13	3.02	4.52
14	0.46	0.76	1.35	1.64	1.91	2.25
15	0.53	0.77	1.35	1.72	2.22	2.80
Median	0.54	0.78	1.36	1.73	2.18	2.80

(b)



(c)

Index flood method of regional flood frequency analysis. (a) single-station flood frequency curve, (b) ratios Q_t to $Q_{2.33}$ for 15 stations, and (c) regional flood frequency curve

FROM: "INTRODUCTION TO HYDROLOGY"

				CLIENT	MINING HYDROLOGY WORKSHOP
				PROJECT	FLOOD - FREQUENCIES AND VOLUMES
				SUBJECT	INDEX FLOOD METHOD
0		FIRST ISSUE		HE	HYDROCON ENGINEERING (CONTINENTAL) LTD
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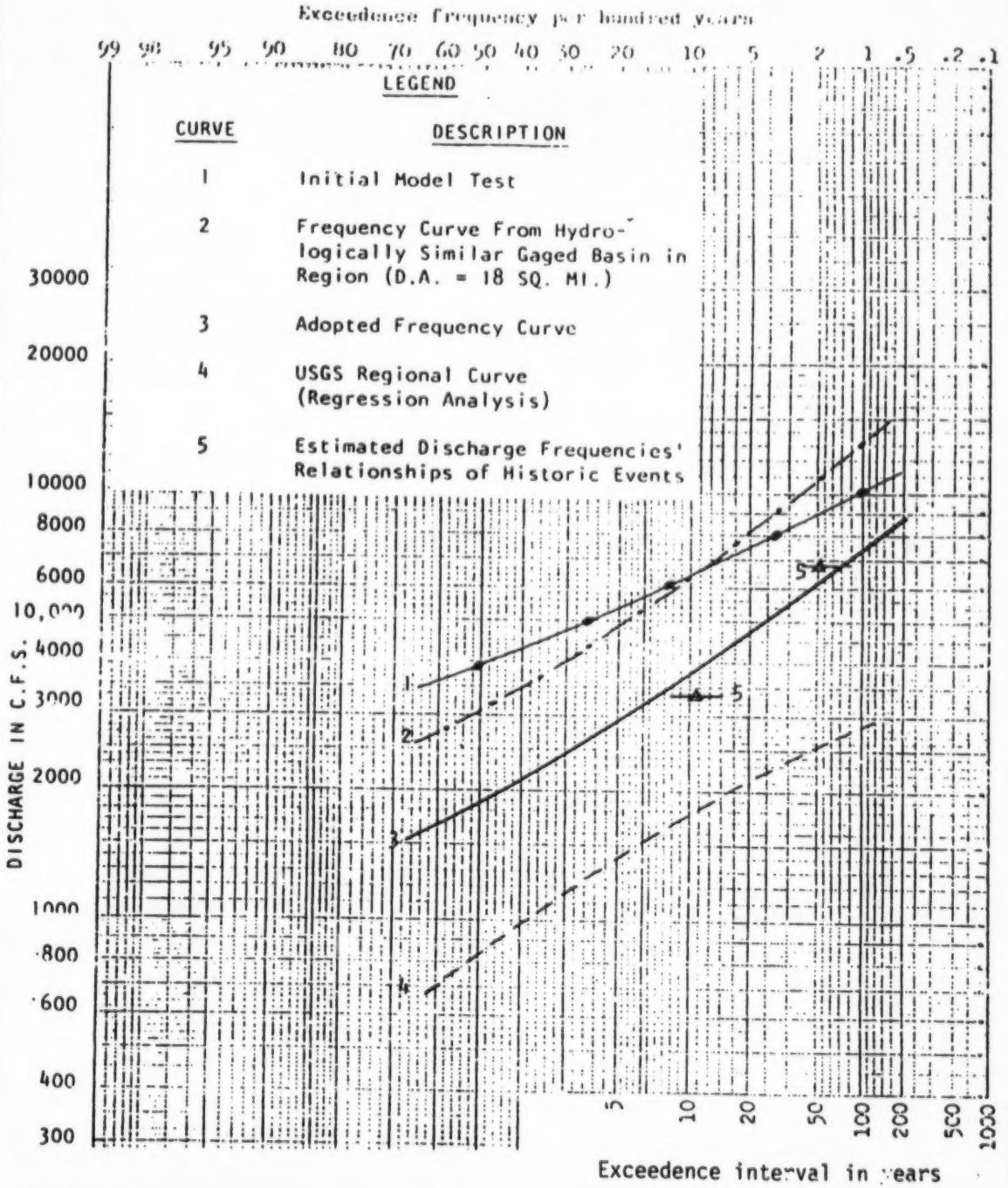

LOST CREEK
Discharge Frequency Curves
D.A. = 14 sq. miles

FROM: "TRAINING DOCUMENT II."

0		FIRST ISSUE			
REV.	BY	DESCRIPTION	DATE	APPR'D.	

CLIENT: MINING HYDROLOGY WORKSHOP
PROJECT: FLOOD - FREQUENCIES AND VOLUMES
SUBJECT: COMPARISON OF METHODS - CASE HISTORY

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DP 001A HEL

Calculating Flood Frequencies and Volumes
Gary Beckstead, Hydrocon Engineering

P. ZIEMKIEWICZ

In a lot of models you find that one or two independent variables are impossible to estimate reliably. Do we have a situation like that here, or are all your independent variables fairly accessible?

G. BECKSTEAD

I would say that most of them are (accessible). I think that what we can easily get a handle on are those parameters that are going to get rid of the residuals that are causing the most noise in the data. I don't think you have to get too specific.

P. ZIEMKIEWICZ

Do we have a good handle on infiltration, for example? Is that easily come by?

G. BECKSTEAD

I think you can get a pretty good handle on things without going to that level of sophistication. You can essentially do the study as an office study, using maps and published data.

R. MILLSON

Is that currently your normal approach?

G. BECKSTEAD

It depends on what level of effort required on a particular study.

Effects of Pollutants on Stream Life
Bill Costerton, University of Calgary

R. FESSENDEN

Have you looked either experimentally, or in a field situation, at the effect of siltation on these populations of sesile micro-organisms?

B. COSTERTON

The richest place for bacterial growth that we know of in the microbial kingdom is the sediment in the bottom of settling ponds, particularly if you've got a fairly decent organic input coming in, and that's where we found some of our highest values.

R. FESSENDEN

Do you get a physical exclusion of suspended particles because of this anionic or cationic resin?

B. COSTERTON

The key thing is why do the bacteria produce such huge amounts of spunge around themselves? The quick answer is that is a sponge for organics picked out of the environment and down in the sediments you've got clay particles and sponge then more sponge down the the cells. In fact, that sponge loads from the outside, so it is a way of carrying organics down deep into the sediments and when this is done, even down into the anerobic levels, we can see by autoradiography now, the turnover in those systems. So there is no effect of substrate inavailability to the lower-most organisms.

H. REGIER

You are literally feeding these bugs organics so that the population increases. What happens when you quit feeding them and the population decreases? What happens to these metals? Are you releasing them?

B. COSTERTON

This is the obvious dynamic aspect that we have to look at. This is what was looked at with the mercury loading. You are getting a total adsorption of mercury into biofilms right close to the source and you only ran into downstream problems when that biofilm did a seasonal dieback - this will happen when there are not enough organics coming in and the biofilm has not got enough to thrive on and starts to die off at the edges and the downstream end and when it does that, it mobilizes all the things it previously trapped and you could hit a real surge of heavy metals as you point out. There is one point I want to make in the Athabasca River, sediment, about 1/3 of it's bacteria are specialized in breaking down heavy hydrocarbons. If you could deprive them of hydrocarbons, you would kill 1/3 off the bacteria.

G. BERGSTROM

We did a study at Luscar Creek. We found that this film that you are discussing ran all the way from below the settling pond to the mouth of Jarvis Creek. That can be a major block to fish. How long do we expect this cleaning process to take place and what effect does it have on the fish population?

B. COSTERTON

I'm disturbed by what you say. Out study was in 1976 and we looked seasonally on monthly intervals. Our resolution was complete by site 8, so we found no increase in the film. We saw fish in large numbers. I think we can extrapolate from the bacterial case. You will see biofilm, but you have to equate if it is above natural levels.

G. BERGSTROM

This was thick all the way down.

B. COSTERTON

I am suprised, that differs completely from our data. Where we had no visible differences at all on site 8 and by the time we got down to the junction with Jarvis, we were back to pristine levels and there was a full species variety of insects.

T. SNEDDON

How much sediment will the biofilms trap?

B. COSTERTON

We analyzed, on Tri-Creek, the amount of clay trapped and found an enormous amount of particulates trapped.

IDENTIFIED RESEARCH PRIORITIES

	SCORE	TOTAL
1. Water Management Systems		39
- Prediction of required capacity (improved models, meterological information, sampling methods, conversion factors for mined watersheds)	15	
- Design and maintenance of water control structures (Floculation, sedimentation systems, tailings dewatering methods)	12	
- Loss of culvert and settling pond effectiveness due to ice formation	5	
- Landscape design - to optimize watershed values (Dump design, resloping schemes, revegetation to forested and non-forested land to enhance runoff characteristics)	5	
- Lake and stream reconstruction (identify critical design parameters)	2	
2. Regional Scale Hydrology		4
- Cumulative effects of multiple mine developments on Eastern slopes watershed	4	
3. Regulatory System		4
- Improve enforcement	2	
- Poor example by other Gov't agencies Construction Practices	1	
- Improve water Quality standards for sediment	1	
4. Water Quality		3
- Effects of sediment quality and quantity on fisheries (e.g. Bentonite vs. Silt)	2	
- Effects of sulfur precipitation on streambeds	1	
5. Groundwater		2
- Mining effects on baseflows of streams	2	

RESPONSES TO QUESTIONNAIRE

RRTAC WORKSHOP
EFFECTS OF COAL MINING ON
EASTERN SLOPES HYDROLOGY

1. One of our objectives in holding this workshop is the definition of Reclamation Research priorities. Based on your experience and conclusions after hearing the Workshop presentations and discussions, what specific research topics would you identify?

   (Include any topic which you feel would enhance the reclamation process and make it more efficient)

   Response No. 1: Problems associated with drainage and the control of water in mines are primarily technical or engineering in nature. These problems may not require any research. I got the impression that the mining companies have put little effort into the design of structures, etc., to adequately control water on their lease. As was obvious from the discussions rainfall of 25mm or so in a 24-hour period becomes a crisis. Also, the structures seem to have been designed only to handle rain water not water from snowmelt.

   Response No. 2: Clearly the presently most pressing concern is in the area of surface hydrology. (1) How does one predict peak flows on a mine site on the basis of pre-mining hydrologic data? (2) How does the removal of vegetation and excavation to new slopes in the various rock and soil materials present in a mine site alter the runoff and sediment yield characteristics of a mine area in the mountains or foothills? The necessary research involves developing relationships between precipitation and runoff and erosion and sediment yield where the proposed operations involve significant alternatives in ground cover and slopes. A secondary question that may be of some concern is whether, and if so, to what degree these changes in groundcover and slope characteristics alter groundwater recharge and therefore might alter base flow characteristics of streams. This could become an issue where large areas of a watershed were mined.

   Response No. 3: There is a lot of hydrological information that is being used, gathered and interpreted for different objectives e.g. watershed management. Little of this has been collated and integrated into one source. This should be done first; then models should be developed to improve the predictability of hydrological events. With 80% failure rate of structures, our view of, say the 1 in 10 year storm is radically different from practicality. The rational formula should be more closely scrutinized particularly with a view to the run-off co-efficient. Threshold values for 'c' with respect to mining should be developed. The hydrological cycle should be quantified, i.e. how much input vs. how much output.

   Response No. 4: A study is required to determine the optimum amount of topsoil

Response No. 4 (cont'd): and/or regolith that is required for reclamation of mined areas and spoil piles. Different depths from (25 cm) 10 inches to (15 cm) 6 inches)but to date I have seen no experimental data to verify that these figures are right. Also degree of slope and aspect will be factors affecting the volumes required.

Response No. 5: Stream reclamation in mine areas: feasibility of channels in backfilled areas. End pit lakes: feasibility; capabilities/design predictive capability for water management, climatic data base: applicability of regional data to site specific needs; multiplier made for increased yield of disturbed vs. undisturbed site, including verification.

Response No. 6: (1) Stream Siltation: Given the degree of siltation of streams which was apparent in some of the slides which were shown at the workshop, it is difficult to believe that there would not be some detrimental effects on the microbes which are attached to surfaces on the stream bottoms - Dr. Costerton's remarks notwithstanding. (2) Erodibility of soils and geological material: In my opinion the erodibility of soils and disturbed geological materials in the mountains/foothills region is not well enough understood in quantitative terms to allow for the proper design and placement of overburden dumps and water management structures. (3) Surface and Subsurface Hydrology: The surface and subsurface hydrology of proposed mine sites and the effect of the mining activity on the surface and subsurface hydrology does not appear to be well enough understood in quantitative terms to allow for the proper design and placement of overburden dumps and water management structures. It might be quite constructive to do a detailed study of a selected area to document the effect of mining on these processes. (4) Regional Impact: Any given mine development may not in itself have a significant effect on the productivity or hydrology of a watershed. However, multiple developments in a watershed might very well have a more significant impact. At present there would appear to be no understanding of how much development in the foothills/mountain region would be acceptable, or for that matter what watersheds are most sensitive. A regional study of surface and subsurface hydrology and soil erodibility might very well be in order. (5) Soil Productivity: Although this issue was not addressed at the workshop, post-mining soil productivity continues to be a topic which needs to be studied in more detail.

Response No. 7: (1) Studies of runoff response and suspended sediment transport from disturbed coal mining areas so that better models can be designed or tested as a basis for better settling pond design. (2) More studies of the actual impact of suspended sediment on the fishery so that more realistic limits on suspended sediment discharge from mines can be established or the present limits evaluated.

Response No. 8: If 88% of the water on the prairies is produced in the east slopes, will there be significant impacts on the water users downstream (i.e. in prairies) from coal mines located in the east slopes region? Will there be significant variation in the post-mining versus pre-mining water quality? Is there irrefutable evidence that selective materials handling is a must for the Eastern Slopes even to a commercial forestry post-mining land use?

Response No. 9: Review design criteria for tailing ponds. Develop small working model for hydrology of such basins. Review public (company) participation regarding improving attitudes of machine operators regarding the environment.

Response No. 10: (1) Runoff coefficients for different types of disturbances. (2) Use of flocculants, different types and methods. (3) Effect of different dump configurations. (4) Shapes and sizing of settling ponds.

Response No. 11: What I have heard dealt primarily with surface water problems during mining and with the difficulty of designing for unusual hydrological events. Reclamation did not seem to be a high priority issue. The reclamation process would be enhanced by a thorough understanding and monitoring of pre-mining, during mining and post-mining hydrological conditions.

Response No. 12: (1) Need a quantitative understanding of the hydrological cycle as it relates to severely disturbed areas in the Eastern Slopes, for example, what is the coefficient of runoff? (2) Need to learn how to manage detritus from mine-site runoff. (3) Do we know what comprises a stable or an unstable basin, i.e. some basins are more sensitive to mining activities. (4) What are the effects of location (roads, shops, etc) on how a basin reacts?

Response No. 13: Practical study of operational techniques during winter-perhaps using bubblers to keep water open at the inlet to ponds and around decant towers. Surface water monitoring of site from exploration to development and finally through to reclamation. To provide site data on runoff amounts and timing as the area is disturbed.

Response No. 14: Do not appear to be any "research" needs as such. Problems appear to be operational or developmental in nature. Also appears to be a possible regulatory problem.

Response No. 15: My impression from the workshop was that existing engineering capabilities were such that many of the hydrologic problems in east slopes mining could be prevented. At no time during the workshop did I see an area where research was necessary, as it related to reclamation.

Response No. 16: (1) Influence of ice on water management systems on mine sites. (2) Impact of mining operations on natural watersheds during and after active mining. (3) Improved gauging methods and sensitivity analysis of gauging networks in small basins. (4) Relationship between sulphur precipitation and abandoned underground workings.

Response No. 17: (1) Prediction of peak flows on mined sites including rain and snowmelt inputs. (2) Landscape design to enhance watershed management. (3) Settling/floculation of suspended Bentonite. (4) Freezing of culverts and setting ponds.

2. Other problem areas may be approached using existing technologies or methods. List the types of problem areas which you feel would fall into this category and the sort of solutions which would be available.

Response No. 1: The problem of watershed protection was not really addressed at the workshop. According to the government's Eastern Slopes Zone Policy, the foothills area being discussed is a prime watershed protection zone. (The major economies of the Prairie Provinces are dependent on this watershed for most of their water). One mine on a mini-watershed in the region may make little difference, however, several of these mines may have significant impact.

I can see a network of watershed studies (monitoring) being required to determine if we have a potential problem if coal mines, etc. continue to be developed in the region.

It also appears that the enforcement agencies have not been carrying out their duties adequately. It may be they lack the tools to enable them to perform their duties adequately.

Response No. 3: On-site management problems e.g. freezing culverts, freezing settling ponds. Solution - maintain minimum flows, identify these. Disposal of oily wastes from workshop areas. Solution develop alternative handling methods. Monitoring - develop more meaningful monitoring techniques that more accurately reflect the true situation.

Response No. 4: Cleared areas, the larger the more effect it has on the speed and volume of runoff. Further or additional studies are required to determine the optimum size of open patches (grassed areas) as compared to tree areas to have a fair retention on runoff. Slope degree and aspect will also affect this.

Response No. 5: Stream reclamation in diversion channels (i.e. use of channels as biological structures as well as hydrological structures), habital creation as per available knowledge on fish biology. Settling basin design relative

Response No. 5 (cont'd): to freezing problems and handling spring runoff conditions. Two designs; total winter retention; alternative outlet structures. In conversation with an engineering friend who has designed ponds, lagoons, and intake structures, there appears to him no reason for not reaching a solution (the constraint is cost). Lack of thorough assessment of settling basin performance. We know there are problems at times but how are the ponds functioning under various conditions and how do they function the majority of time. Automated samples and monitoring equipment should be able to provide much better data.

Response No. 8: The regulations pertaining to the size and nature (design criteria) of settling ponds should be reviewed. There appears to be a lack of flexibility in the design criteria; the results are misproportioned facilities. The lack of good (reliable) site specific meterological data was evident throughout the workshop.Environment Canada and the Provincial Environment Department could perhaps install a meterological station in the Robb and/or Hinton area. There also appeared to be a lack of enforcement from the Edmonton offices. The field personnel do not appear to be given adequate support from Edmonton. The problem seems to stem from the number of government agencies the field people must represent Alberta Forest Service, Fish and Wildlife, Environment, etc. - and the lack of direction in their regulatory duties.

Response No. 10: (1) Use of cuttings as a propagation method. (2) Credibility - a point was brought up Re: convincing mine personnel to do work which is environmentally sound when they see the harmful work done by other government agencies. Example: The Department of Transportation on Highway 40 puts in culverts too high for fish to jump in and swim through; they dump ditch sediments directly above creeks, etc. The government should clean up their act first.

Response No. 12: Compile a history of past failures and reasons for failure so that industry and government can learn from these experiences. Water management facilities seem to be underdesigned. Why?

Response No. 14: (1) Collection and compilation of hydrological baseline data for the region and establishment of a data base for same (permanent in nature). (2) Appears to be a need for more accurate and precise hydrological (predictive) models for mining situations. (3) Adaptation, development or application of technology to solve current or anticipated operational hydrological - related problems (e.g. - frozen pond outflows, frozen culverts, etc). (4) Re-evaluation and possible modification of effluent quality standards.

Response No. 15: The problems related to flood frequencies, water management and mining impacts all seem to be curable through improved modelling, monitoring, engineering and training. I think the water handling problems shown at the existing mines could be rectified in most instances by increased company efforts in the above areas.

Response No. 17: (1) Better design of water and sediment control systems.
(2) Reduction of operator's error.

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